Report. Water
Appendices II & III. 1850.

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GENERAL BOARD OF HEALTH.

REPORT

Th. S. Pollock

ON THE

SUPPLY OF WATER

TO

THE METROPOLIS.

APPENDIX No. II.

ENGINEERING REPORTS AND EVIDENCE.

Presented to both Houses of Parliament by Command of Her Majesty.

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1850.

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LIST OF PLANS, ETC.

ENGINEERING REPORTS.

STATEMENT of the various SCHEMES proposed, and laid before the GENERAL BOARD OF HEALTH, for the improvement of the SUPPLY of WATER to the METROPOLIS.

To the General Board of Health.

MY LORDS AND GENTLEMEN,

IN accordance with your instructions that I should examine the various schemes that have been brought to your notice for the improvement of the supply of water to the Metropolis, and lay before you a general description of the whole, I have the honour to present the following statement. [Mr. Austin.

They are twenty-five in number. Eleven of these consist of plans for bringing the supplies directly from various parts of the river Thames between Twickenham and Mapledurham; seven of the propositions are for supplies from various tributaries of the Thames; three are for supplies from springs, and four from shafts, or so called "artesian wells," sunk into the chalk of the London Basin. Ten of these schemes are or have been represented by Companies, or have emanated from engineers officially engaged, and the majority of these have been from time to time before the public in printed descriptions and prospectuses.

It would exceed my instructions to enter here upon any enumeration or historical record of the many plans which have been brought forward in former times, or to advert to the proceedings which took place before the Committee of Inquiry in 1828; but before entering upon a description of the plans immediately before the Board, I would beg to notice those which were prepared by the eminent engineer, Mr. Telford, in 1834, and which were the result of that inquiry; not because these plans are now again brought forward or represented, but because considerable attention has from time to time been directed to them, and because the inquiry into the means of improving the supply of water to the metropolis, may be said to be up to the present date nearly in the same position in which it was then left.

Mr. Telford's investigations were undertaken in consequence of directions received by him from the Lords Commissioners of Her Majesty's Treasury, to report "in what manner the metropolis can be supplied with pure water;" complaints having then been urged against the supplies from the river Thames, and the Committee of Inquiry having reported that they ought to be derived from other sources.

Mr. Telford states in his Report,—"The water of the river Thames being strongly objected to by the inhabitants of this great city, and also condemned in the Report of the Commissioners of

Mr. Austin. Water Inquiry (see Report 27th April, 1828, p. 11), in consequence of the impurities with which it is contaminated; I therefore perambulated the district on each side of the valley of the Thames, and examined the streams which fall into that river in the vicinity of London." The result of this investigation was the plan to bring water from the river Verulam for the supply of the districts on the north side of the river Thames, and from the river Wandle for the supply of the districts on the south side.

A reservoir was to be constructed at the Verulam, near Watford, whence a covered double aqueduct was to convey the water to a service reservoir on Primrose-hill, a distance of upwards of 15 miles, from which the distribution was to be made by the existing Companies, the Grand Junction, West Middlesex, and Chelsea. The estimate of cost of the works was 785,965*l.* 11*s.* 6*d.*

From the Wandle at Beddington, near Croydon, a covered aqueduct of similar character was to convey the water to a reservoir on Clapham common, a distance of upwards of six miles, whence it was to be distributed by the Lambeth, South London, and Southwark Companies. The estimate of cost of the works was 391,875*l.* 4*s.* 11*d.*

From information obtained by the Commissioners of Inquiry in 1828, it appeared that the average daily supply of water afforded by the Grand Junction, West Middlesex, and Chelsea Companies on the north side of the river, was 6,810,000 gallons, or nearly 13 cubic feet per second; but in order to provide for the maximum demand in 1833, and for future increase, Mr. Telford proposed that 30 cubic feet per second should be obtained from the Verulam.

The average daily supply afforded by the Lambeth, South London, and Southwark Companies on the south side of the river was 2,964,000 gallons, or 5½ cubic feet per second, and Mr. Telford proposed to receive from the river Wandle 13 cubic feet per second.

The total quantity of water therefore proposed to be supplied to the metropolis at that time was 23,220,000 gallons per diem, to afford which the total estimate of cost of the works was 1,177,840*l.* 16*s.* 5*d.*

In 1840 Mr. Robert Stephenson made a report to the London and Westminster Water Works Company—at that time established for supplying the metropolis with water from springs in the chalk near Watford—in which after alluding to the unsatisfactory mode in which London was then supplied with water, he states,—"It is indeed surprising that, with the exception of the proposal to obtain the water by perforating the London clay, every project, including Mr. Telford's, should have contemplated using the water of streams which are all subject to be affected by the surface drainage of a more or less extensive tract of country, and consequently only a very few degrees better than that already in use;" and further

on he repeats,—" that it is scarcely to be wondered at that the Legislature should have delayed acting on Mr. Telford's plan, which combined these objections with a very large outlay, nor that a Company should still have found grounds for proposing artesian wells in preference to his suggestions." Mr. Austin.

With regard, however, to the artesian schemes referred to, and which are again brought before the public, Mr. Stephenson proceeds to give very conclusive reasons for insufficiency of supply from such a source.

No estimate of cost of the proposed plan of water supply from the chalk at Watford is given in Mr. Stephenson's report, it being mainly directed to show that the necessary supply for London could be obtained and conveyed from that source.

The plan thus proposed was in part revived during last year by the London (Watford) Spring Water Company, and a Bill introduced in the present session of Parliament for carrying it out. The plan of obtaining the supply appears to be virtually the same as that of Mr. Stephenson, but it is said to be " in part revived," because instead of the present scheme being intended for a complete metropolitan supply, it is only proposed now to bring in 8,000,000 gallons per day for the supply of the northern districts. It is proposed to raise the water from wells in the Bushey meadows, and conduct it through cast-iron pipes into reservoirs on Stanmore Heath, whence it is to be led to another reservoir at Child's Hill, near Hampstead, and from this the water would be conveyed to Oxford-street, or in any other convenient direction to London and Westminster. It is intended also to supply some suburban districts on the way.

The estimate of cost is 350,000*l.*

Two other schemes before Parliament during the present session were for obtaining new supplies directly from the Thames, one from near Henley, the other from near Mapledurham. For the first, notices were given by a Company in the previous session, but the Bill was lost on the second reading in the Commons. It was renewed in the present session with the proposition of its being managed by a metropolitan Commission. It is proposed that an open canal 40 feet wide and 10 feet deep, should convey the water from the Thames near Medmenham Abbey to West Drayton, thence a smaller open canal would extend to the river Brent, from which point two brick culverts of 10 feet diameter would convey the water to a reservoir at Hampstead, from which it is proposed to raise it by steam-power to another reservoir 250 feet above high water. The total distance is 33½ miles.

From the Thames to West Drayton 200 million gallons are proposed to be conveyed daily, whence 100 million gallons are to be brought to the metropolis by the Grand Junction Canal, for the purpose of flushing the sewers, and 100 millions to be conveyed by the proposed canal and culverts to Hampstead for the daily

Mr. Austin. supply to the inhabitants. The estimated cost of the works is 2,000,000*l.*

In the prospectus or exposition of the measures proposed to be taken by the promoters of the Mapledurham scheme, of which Messrs. Gordon and Liddell are the engineers, it is stated that— "There is no source of water within the Thames basin from which a supply sufficient for the wants of the metropolis can be obtained excepting the river Thames itself," and that "the Thames at Mapledurham lock has been proved to be purer than at any other point below its source." It is therefore proposed to bring 50 million gallons daily supply from the Thames at this point, and to convey it by an open canal for a distance of 4½ miles into four reservoirs at Caversham. The promoters state further that "the water of every spring in the Thames basin, and of every river flowing through it, is hard. Hard water is unfit for most domestic purposes." And therefore the proposed supply is to be submitted to Dr. Clark's process, and then raised by steam power and conveyed to London through three iron pipes 5 feet diameter, following the line of the Great Western Railway.

In addition to the 50 million gallons thus to be daily supplied, it is proposed that the supply of 12 to 13 million gallons afforded by the New River should be still available for sanitary purposes.

The cost of executing this scheme is estimated at 1,200,000*l.*

Mr. Quick, the engineer of the Vauxhall and Lambeth Company, and consulting engineer of the Grand Junction Company, has proposed to bring a complete supply of water for the metropolis from the Thames at Eel-pie Island, Twickenham, considering that there would be no advantage corresponding to the increased outlay to be obtained by taking it from any point higher up the river.

The arrangements proposed by him would deliver the water filtered to the distributing pipes of the present Companies, but would dispense with all the existing pumping establishments. The cost of the works for the daily distribution of 50 million gallons from this point, Mr. Quick estimates at 300,000*l.*

In 1846, the promoters of the proposed "Aqueduct Company," brought forward a scheme for the supply of water to the metropolis from the River Thames, near Amerton Bank, about a mile and a half south-east of Maidenhead, at which point, according to Mr. Hawksley's report, it may "be received and filtered in immense volume; that it may thence be conveyed by a properly constructed tunnel to a point immediately below Hampstead-hill; that it may then be raised by the action of powerful steam-engines into elevated reservoirs, and afterwards be distributed through the metropolis and its suburbs, by communications to be made, for the most part, with the works of the existing Companies."

Mr. Hawksley estimated that within twenty years the population of the metropolis would amount to three million persons, and that the future daily consumption of the whole metropolis may be

assumed at 75 million gallons; that the quantity which would Mr. Austin.
still probably "be supplied from the existing works and machinery of such of the Companies as derive their supply from sources, the character of which is neither now nor hereafter likely to become unfit or objectionable," could not be taken at more than 25 million gallons, and "consequently that a demand upon the works of the intended Company, of not less than 50 *million gallons per day*, may be expected within the term for which provision is now proposed to be made."

In this scheme it was proposed to establish on the banks of the Thames near Bray, ten subsiding tanks of five acres each, and ten filter beds of two acres each. The tunnel or aqueduct to convey the water to Hampstead was to be of brick, 12½ feet in diameter, and here were to be ultimately established 12 engines of 250 horse power each, for raising the water into elevated reservoirs.

The total estimate of these works was 746,790*l*.

Mr. P. W. Barlow, the engineer to the South Eastern Railway Company, proposes to obtain the supply of water for the metropolis by the interception of the springs which issue from the chalk, and discharge into the River Thames along the North Kent district between Greenwich and Strood. Professor Ansted, in a report to the Directors of the Railway Company, states, "that there exists, at a moderate depth, a supply which is practically inexhaustible." In a further report he adds, "that the whole of the chalk between Erith and Gravesend is saturated with water, considerably above the level of low-water level, and that a very large supply, equivalent to several millions of gallons per day from these localities only might readily be intersected by a tunnel or number of bores, and is fully available without interference with existing interests."

Samples of this water taken from Charlton, Abbey Wood, Northfleet, and Strood, were submitted to Professor Brande for examination. The detailed analyses of these four samples (together with that of a sample from a well at the Bricklayers' Arms Station, which is a very different character of water, assimilating to that of the deep wells of London,) are given in a report by Professor Brande addressed to Mr. Barlow, from which it appears that their degrees of hardness range from 22·5 to 26·3. Mr. Barlow proposes to intercept this water by constructing a heading, or small tunnel, along the course of and underneath the line of the North Kent Railway, with borings every half mile, affording a supply of 100 million gallons per day.

The cost of the works for bringing the water to the railway terminus at Bricklayers' Arms, he estimates at 150,000*l*.

Mr. Rendel, the engineer, although he has proposed no specific plan for improved supplies of water to the Metropolis, expresses some opinions on the subject in a report recently issued on the proposed improvements of the river Lea navigation, which it ap-

Mr. Austin. pears desirable to include in this description. In alluding to the quantity of water delivered at Feilde's weir on that river, Mr. Rendel states:—

"It does not come within the scope of this report, limited as it is to the description and objects of the works shown on the plans now before Parliament, for the improvement, &c. of the navigation, to devise a plan for making this water available to the supply of London, or to discuss the mode of dealing with the several interests involved; but it is clear, that when the question of making such supply is fully gone into, as it assuredly will be ere long, advantages such as the Lea possesses cannot be neglected; particularly when it is remembered, that not only is the available quantity of water very large, and its quality excellent, but that the means by which it can be supplied are already in existence; I mean the New River, which is not more than 100 yards distant from Rye House, up to which Feilde's weir pond extends. But it will be said, that the New River is not a suitable channel for its conveyance to London, in a manner that will satisfy the consumer. It is no part of my duty to say how the course of the New River may be improved, to obviate such objections. I may, however, call your attention to the fact, that all the objections which apply to the New River in this respect, apply to any other open conduit, whilst the expense of removing them by suitable alterations, would not probably amount to the cost of purchasing the land of any new conduit.

"The river Lea being in my judgment the most eligible source from which to get the necessary additional supply of water for London, it appears to me that you, the only public body having a Parliamentary interest in the river, as trustees for the maintenance of its navigation, should take the initiative step, by acquiring, before any abstraction of the water is allowed, such powers as would enable you to place the public interest which you represent, in a safe condition, and also remove, as far as practicable, the consequences to the mill-owners. As the promoters of a measure of this kind, you, in your capacity as trustees, with no personal or pecuniary interest in the question, are in a condition to protect the private interests with which your public trust is associated; not certainly to the extent of depriving the metropolis of water which may be parted with, after other interests are protected, but by obtaining powers from Parliament that shall secure the navigation beyond all doubt, and at the same time provide a means of guaranteeing the mill interest on the river from loss of the water usefully available, without adequate compensation."

Captain Vetch, in his evidence, has laid before the Board, a comprehensive scheme for the supply of water to the metropolis from various sources. In alluding to the ratio of increase of the population of the metropolis, he states,—"I consider it a most important measure to secure all the best supplies of water that

can be obtained near London, before they be appropriated to other objects of minor importance." The supplies referred to appear to be the river Verulam, the Colne, the Gade, and the Chess, and the river Lea and other streams of that neighbourhood on the north side of the Thames, and those of the river Darenth, and the Mole, on the south side of the Thames. These waters Captain Vetch proposes to conduct to elevated reservoirs in the neighbourhood of the metropolis, chiefly by means of tunnels or adits in a direct course, affording a supply of 100 million gallons daily. No estimates of the proposed works are given. The proposed lines of aqueduct are marked on the accompanying map, and as Captain Vetch's views are set forth at length in his evidence, it will be unnecessary to enter more fully here into a description of the schemes presented by him. In referring, however, to the means of conducting the supplies from their sources, it may be useful to allude to the objections set forth in his evidence, to open tortuous channels, such as that of the New River Company. "Within the present century," Captain Vetch remarks, "great ingenuity and great expense have been applied by the New River Company, to correct the evils of the rude and vicious mode of conduit first adopted, and little more improvement can be effected in that direction, indeed such praiseworthy zeal would be better applied to change the system entirely; but probably the very great misapplication of funds and talents to perfect in detail what was defective in principle, may have served to protract the existing works in their primitive form to the exclusion of others more capable of meeting the demands of the day." Mr. Austin.

In referring to the river Verulam, Captain Vetch observes:— "It seems the more necessary to secure this source of supply for the public benefit, as its good qualities are too well known to allow it to remain long unfingered by some commercial Water Company." And, alluding to the Watford scheme already described, he adds:—"Indeed there is a Bill before Parliament this year, which proposes to appropriate the same, and to drive it up by steam-power to high reservoirs at Stanmore, Elmstree, Harrow, and Hampstead, for the supply of the outskirts and country villages; whereas it may flow by gravitation high enough for the wants of the great metropolis."

In referring to the Henley scheme now before Parliament and already described here, Captain Vetch observes:—"If for the sake of argument, it be admitted that the object of the promoters of this scheme is exclusively that of supplying London with water for domestic purposes, then all the objections I have stated to the conduit of the New River will equally apply to the open channel proposed for this scheme." In allusion to the Mapledurham as well as the Henley scheme, upon the question, "If the water were permitted to be taken from the Thames above the influence of the tides, where do you conceive it would be most convenient to

Mr. Austin. take it from?" Captain Vetch observes:—"As near above Teddington Weir as local circumstances would permit," and gives his reasons for preferring that it should be abstracted from a point near Twickenham, and conveyed as proposed by Mr. Phillip Taylor in 1824, rather than from any higher point up the river.

Mr. J. P. Thompson's scheme, for which a Company has been formed, under the title of "the Wandle Water Company," is, according to their prospectus, intended "to furnish the inhabitants of the metropolis south of the Thames, and those of Brixton, Clapham, Dulwich, Norwood, Sydenham, Wandsworth, Putney, and other adjacent places, with a cheap, abundant, and constant supply of pure and wholesome water," obtained from the river Wandle. It includes a plan for the drainage of the whole of the towns and villages along its course from Croydon to the Thames at Wandsworth, so as to intercept the whole of the refuse which now discharges into the Wandle, and apply it to the enrichment of the land.

It is proposed "to take the water, in its unpolluted state, at Wandsworth, *after it has done its work for the mills*, and raise it to reservoirs on Wimbledon Common." With respect to quantity, it is stated that "the river Wandle, as proved by the most careful and scientific gauging, yields a minimum supply of upwards of 27 million gallons, and a maximum of upwards of 44 million gallons per diem."

The estimate of the cost of works is 250,000*l.*

A prospectus and report has been laid before the General Board of a Company which has been registered, having the title of "The London and Medway Double Service Fresh and Salt Waterworks Company, for obtaining a constant supply of pure water from the river Medway, and its tributaries, the rainfall of the Tunbridge and Holmsdale valleys, the river Darenth and the River Cray, all of them situate in the county of Kent. And for establishing a permanent salt-water sanitary service for the metropolis, by supplies of sea-water drawn from the estuary of the Medway."

The prospectus states that "the district to be supplied contains on a rough estimate, 100,000 houses, of which 60,000 are either partially or wholly unsupplied with water," and "in addition to its own independent labours, the Company will seek to supply the Lambeth, Southwark, and South London Water Companies, with pure soft water, in lieu of the hard unwholesome water which they are at present compelled to distribute." Further on it is stated, "that the London and Medway Company will enjoy a command of water sufficient for all the uses of a city twice the size of the existing metropolis."

It is proposed to collect the waters, at suitable points, in vast reservoirs, and to carry them by the line of the North Kent Railway, in four large main pipes, to Kidbrook, near Blackheath, whence it would be distributed by gravitation.

The principal objects of the "salt-water service" are stated to be "1st, The daily cleansing and purification of the streets; 2nd, Flushing the sewers and purification of the Thames; 3rd, Supply of public and private baths; 4th, Extinction of accidental fire." Mr. Austin

No estimate of cost of any of the works is given, but the proposed capital of the Company is 400,000*l.*

The scheme for supplying the whole metropolis with water from "Artesian" wells sunk into the chalk of the London Basin, appears to have been advocated, for some time, by the promoters of a society, under the title of "The Metropolitan Water Supply Association; for establishing the whole water supply of London, and its suburban districts on a self-supporting principle, through the medium of one public institution, directly responsible to the inhabitants; and for insuring an abundant continuous supply of pure soft water to all classes throughout the metropolis."

No plans of the arrangements proposed for carrying out this scheme have been brought before the General Board, nor any statement of the quantities proposed, nor estimates of the cost of the works.

Having now briefly described the main features of the whole of the schemes for an improved supply of water, which have been more prominently brought forward, and have been for the most part represented by Companies, I shall proceed to notice in the same manner those suggestions which have been laid before the Board for the same object by their individual authors.

Mr. James Dean, of Tottenham, purposes to obtain the supply of water from the river Thames, between Kingston and Richmond, conveyed into reservoirs on the banks of the river, in the bottom of which reservoirs, should additional supplies be required, he proposes to sink shafts into the chalk, from which he entertains no doubt that any amount of water may be obtained. No estimates are given of the proposed plan.

Captain Hood, R.N., has laid before the Board a voluminous paper on the subject of the supply of water to the metropolis, and an extensive plan of the valley of the Thames, evidently the result of the devotion of very considerable time and personal labour to the subject. The main feature, however, of Captain Hood's propositions is, that it would be perfectly useless to go such a distance up the river Thames for the supply of water, as proposed either by the Henley or the Mapledurham scheme, when it could be equally well obtained from near Maidenhead.

Dr. Dowler lays a proposition before the Board for obtaining the supplies from the river Thames, just above Teddington locks.

Mr. Hardinge proposes the Thames at Staines.

Mr. H. H. Fulton purposes also to obtain the supplies from the River Thames at Staines, diverting from the river the sewage of the towns now discharging into it above that point. "This

Mr. Austin. plan," he states, "as compared with the Henley project, would shorten the length of the principal conduit by 18 miles, and occasion a saving more than equivalent to the expense of diverting the sewage from the whole of the river above Staines." It is proposed that the water should be brought in a close conduit, in the direction of the western road, to the north-west of London, where it should be raised to the heights required for distribution.

No estimates are given of the proposed works.

Mr. B. Denton proposes "to unite, by an open or covered channel, the surplus water of the Thames, *i. e.*, as much as may be required and attainable, after a due provision for navigation, with the water of the Colne, a little above Colnbrook, and by the course of that branch of the Colne, called the Queen's river, convey it to *Feltham*, at a point where the latter crosses the 'Windsor, Staines, and South-Western Railway,' at the summit of that line. The point from which it is proposed to take the water from the Thames is a little above Boulter's Lock." It is proposed to construct reservoirs adjacent to the railway, and carry the water "by pipes laid within the property of the South-Western Railway Company, to such points as it would be most convenient for diverting into courses of supply, or for raising to a higher level for high service." It is stated that 50 million gallons should be supplied daily from these sources, leaving other 50 millions to be supplied by the New River and East London Companies to their respective districts. No estimates of the cost of proposed works are given.

Mr. James Green proposes to obtain a supply of pure water from the Thames, without going so high up as to be beyond the tidal influence, by converting a part of the course of the river into a canal, and thus cutting off the impurities which at present contaminate the water.

Mr. William Baker proposes to conduct the waters of the river Chess, in Hertfordshire, to London, taking the supply at about a mile below the town of Chesham. He estimates that 25 million gallons per day may be obtained, which he believes to be double the quantity supplied by all the present Companies. The cost of the works is calculated at from 250,000*l.* to 300,000*l.*

Mr. T. H. Liberty proposes to make the Basingstoke canal available for the supply of water to the metropolis, receiving, in addition, certain springs at Frimley, which now flow under the canal for the use of mills. It is estimated that the canal holds 76 million gallons, which, with the addition of the springs referred to, Mr. Liberty conceives would keep up the supply. He calculates the cost at 465,000*l.*

Mr. W. Rae proposes to obtain the supplies from Artesian wells, a Company being formed in each parish for the purpose.

Mr. John Pym proposes to obtain the supply of water by sinking, "at a given distance from the Thames, on each side of

Mr. Austin

the river, a series of shafts, down to the chalk, say one or more every quarter of a mile, each shaft to have a canal or aqueduct communicating with the Thames, between high and low water-marks, through this aqueduct a stream would flow for a given period, twice every day, to fill these shafts, and ultimately fill the chalk basin. At a convenient distance from this descending shaft another shaft should be sunk, into which the filtered water would flow as in an inverted syphon, until it rose to near the level of the water in the Thames."

The plan proposed by Mr. F. F. Couch for obtaining the supplies is identical in principle with that of Mr. Pym.

In the foregoing description of the schemes which have been recently brought before the Board for the improvement of the metropolitan water supply, I have confined the statement to a mere description of the leading features of the plans, as set forth for the most part by the authors or promoters themselves. Several of the papers which accompany many of the promoters' proposals are mainly occupied in showing the impracticability of, or objections to, other of the plans which are rival to their own. It has not appeared to be necessary to remark upon these statements, or in fact to enter upon any comparison of the schemes set forth, to do which effectually would have required considerable time and a far greater amount of information than has been afforded. Although it will be obvious that several of the plans presented are of an impracticable character, and emanate from persons possessing no acquaintance with the subject, I have thought it right to mention the whole of the schemes that have been brought to the notice of the Board.

With reference to the amount of improvement over the present modes of supply, which appear to be offered by many of these proposed schemes, I would beg to offer one or two general remarks which occur upon an examination of their leading features.

As to improved sources of supply, and the promise of better qualities of water therefrom, it will be observed that twenty out of the twenty-five schemes enumerated propose still to obtain the supplies either from the river Thames itself, or those of its tributaries, the qualities of the water of which, in its original conditions, differ in a very immaterial degree. While the inherent objectionable qualities of these waters appear for the most part to have been overlooked, the great aim has been, from the time of Mr. Telford's plan to the present, to obtain a supply as free as possible from organic impurity, for which purpose several of the new schemes propose to obtain supplies of the same water as at present delivered, taken from higher up the river Thames or its tributaries, or to intercept the large amount of refuse which now discharges into them. With reference to the comparative quality of the water taken from the Thames at the highest point proposed, I would beg to direct attention to the report of Messrs. Brande,

Mr. Austin. Cooper and Taylor, addressed to the Directors of the Southwark and Vauxhall Water Works Company; and as to the objectionable qualities of the spring water from the chalk of the North Kent district, which may be said to be perfectly free from organic impurity, but yet totally unfit for domestic uses, I would also refer to Mr. Brande's analyses of these waters, already referred to.

Evidence has been laid before the Board on the qualities of the water from the deep wells in the chalk of the London basin. Upon the probability of obtaining supplies from this source to meet the consumption of the metropolis, the statements of Mr. Robert Stephenson and the evidence of Mr. Braithwaite may be consulted.

Instructions were early given by the Board for an examination of the waters of the valley of the Medway, the results of which have already been laid before them.

With regard to any proposed improvements in the Management of the water supply of the metropolis, it will be observed that the majority of the proposals consist of the introduction of additional Companies over the same fields of supply, or at the best, a substitution of one Company for another. Of the propositions which are not brought forward by Companies, two only enter upon the important question of management, and these propose the appointment of a separate parochial Commission for sole jurisdiction over the water supply.

In four other of the schemes only is any point made of improved modes of supply, and these recognise only the importance of a continuous over an intermittent system. In Mr. Quick's statements will, however, be found some judicious suggestions for at once affording a continuous supply to courts and blocks of tenements, which have already been put in operation with good effect, and which, as an intermediate course pending the establishment of complete measures, are well worthy of consideration.

While none of the schemes, with this exception, can be said to point to the extended improvements which appear to be so necessary in the modes of distribution and apparatus, or to that combination of works of water supply and drainage, of delivery of water to the house and the discharge from it, which all the sanitary inquiries have shown to be indispensable to the improvement of the healthful condition of town populations,—with regard to quantity, nearly the whole of the schemes, where the question of quantity is mentioned at all, propose to afford a far larger amount of water than is at present delivered. Although none point to the means of economizing the supplies, of preventing the present immense daily loss of water and the evils of this waste in the low districts, the quantities for the most part proposed would far exceed those which all the inquiries instituted by the Board have shown to be sufficient.

The results of the inquiries in which I had the honour to take

Mr. Austin.

part, in conjunction with the Superintending Inspectors, as to whether the sand districts of Surrey would not afford adequate supplies of water of far superior quality to any that were pointed out in the schemes before the public, having from time to time been laid before the Board, in which all were agreed, it will be unnecessary to enter in this place on the points of comparison with the schemes here described; but I would beg to repeat, that the very short period that has of necessity been allowed for that examination, attended although it has been with such promising results, has in no way done justice to the subject. The view obtained has been also over a limited area only, no opportunity having been so far afforded us of extending the investigation over the more westerly parts of the district described by Mr. R. Austin, or the more southerly district of the sources of the Wey. It would be be most desirable that this extended examination should be made, as it may very materially enlarge the view of the capabilities of the district, and modify the calculations that have been made thereon.

I have the honour to be,
My Lords and Gentlemen,
Your very obedient servant,
HENRY AUSTIN.

Mr. Rawlinson.

REMARKS on the CROTON AQUEDUCT, New York; and on Ancient and Modern Works of Water Supply. By ROBERT RAWLINSON, Esq., Civil Engineer, Superintending Inspector.

In 1774, the population of New York was 22,000.

Cost of first Water-works at New York.

Expenses	£. 2,500
Land and materials	8,850
Total .	11,350

A reservoir was formed, and a well was sunk on the east line of Broadway. But the war of the Revolution, which broke out in 1775, retarded the completion of this work, and the town appears quickly to have outgrown it.

In 1798, the Bronx river was proposed; this scheme was not, however, matured. But the same year, the Manhattan Company was incorporated, with powers to supply the citizens with pure and wholesome water. They rejected all foreign sources, and sunk wells within the city limits. The quantity of the water obtained was deficient, and the quality most objectionable. The scheme proved unsatisfactory.

In March, 1822, the mayor brought the deficient state of the water supply before the Council, and a Committee was appointed to consider the subject. The principal source of the Bronx river was again sug-

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gested. Yellow fever prevailed in the city during this summer, which, no doubt, quickened the civic desire to obtain some better supply of water. The engineer appointed to examine the district, and report on the contemplated scheme, seems to have been delayed, as the report was not handed in before January, 1824. 3,600,000 gallons of water were to be furnished at an estimated cost of 1,949,542 dollars. In the following year, a Company was incorporated, styled the "New York Waterworks Company." Water was to be taken from the Bronx at Underhill's bridge; from where the engineer reported that 9,000,000 gallons could be obtained at a cost not exceeding 1,450,000 dollars. The Sharon Canal Company had, however, in the meantime, forestalled the Waterworks Company, and defeated this project, so that in 1827 this Waterworks Company was dissolved.

In 1831, the Common Council again cast about them for a supply of water; and the frightful ravages of cholera in 1832 quickened their operations. The Croton river, distant 38½ miles, was thought of. An open aqueduct was first suggested; but finally a closed aqueduct of masonry was decided upon. The cost of the work, as estimated for this plan, and presented to the Water Commissioners, (including the cost of the city mains and conduits,) was 5,412,336 dollars.

The construction of the work was commenced in May 1837; and on the 22d June 1842, the aqueduct first received the water from the fountain reservoir on the Croton; on the 27th June, the water entered the receiving reservoir at the city of New York, and was admitted into the distributing reservoir on the 4th of July.

The available capacity of the fountain reservoir is said to be 600 millions of gallons. The medium flow of the Croton river, where this fountain reservoir is formed, exceeds 50 millions of gallons in 24 hours, and the minimum flow is said to be about 27 millions of gallons. The aqueduct is 7 feet 5 inches wide at the springing of the arch, which is a semi; and across the invert, the width betwixt the side walls is 6 feet 10 inches, from the invert to the soffit, 8 feet 5½ inches high. The American engineers estimate that it is capable of conveying 60 millions of gallons each 24 hours. The curves which are used to change the direction of the line of the aqueduct are not less than 500 feet radius. Some few have a radius of 1,000 feet and upwards, but the majority of them are of 500 feet radius. There are waste weirs for surplus water, as also six stop-chambers and waste-gates, out of which the whole body of water may be discharged, leaving the length of aqueduct below free for examination and repairs. On each mile there are chimney ventilators, rising 14 feet above the surface, and every third is fitted with a side entrance. At every quarter of a mile, openings 2 feet square are formed in the arch, which are in general covered over with a flag-stone; they may be used either for entrance or for extra ventilation at any time such may be required. The bottom of the water-way of the aqueduct, where it leaves the gate-chamber, is 11·40 feet below the surface of the fountain reservoir, and 154·77 feet above the level of mean tide at the city of New York. The aqueduct has several planes of descent from the gate-chamber at the Croton dam to the receiving reservoir on the island of New York, as shown by the following table, commencing at the south side of the gate-chamber at the Croton dam:—

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	Length.			Gradient, in Feet.	Fall per Mile.	Extra Fall where Pipes are used.
	Feet.		Miles.	Feet.	Inches.	Feet.
1. Plane of Aqueduct .	26,099·72	or	4·943	2·94	$7\frac{1}{8}$	..
2. Ditto ditto .	148,121·25	,,	28·053	30·69	$13\frac{1}{4}$	..
Length of Pipes across Harl River . . .	1,377·33	,,	0·261	2·29	..	2
3. Plane of Aqueduct .	10,733·14	,,	2·033	2·25	$13\frac{1}{4}$	..
Length of Pipes across Manhat Valley . .	4,105·09	,,	0·777	3·86	..	3
4. Plane of Aqueduct .	10,680·89	,,	2·023	1·60	$9\frac{1}{2}$	..
Total . . .	201,117·42	or	38·090	43·63	..	5*

* The extra fall of 5 feet would have been avoided if the aqueduct had been continuous. It is to compensate for the friction in the syphon pipes.

With a depth of water 2 feet, the flow throughout the entire aqueduct is said to have been one mile and a-half per hour. The receiving reservoir is divided into two unequal areas; the northern division covers 18·13 acres; the southern division 12·75 acres, making in both nearly 31 acres. The greatest depth of water is 20 feet, and the capacity of both divisions, when full, is 150 millions imperial gallons. These reservoirs are open and exposed.

Such is a brief sketch of this celebrated work, which was estimated at $5\frac{1}{2}$ million dollars, but is said to have cost upwards of 12 million dollars, a sum equal to 71,000*l*. per mile, placing the whole cost in contrast with the length of the aqueduct. But if the cost of the reservoirs at both ends, and the distributing apparatus is deducted, the actual cost of the aqueduct is upwards of 40,000*l*. a mile, equal in cost to some of our most expensive and extravagantly constructed railways.

In examining the Croton aqueduct, there are several things to be considered, as example, and also as warning. It was a bold step in modern times, to cast about and look for the best supply the district would afford; and contrary to existing usage, fearlessly to undertake a work which may be fairly considered to parallel the great works of antiquity. That water may with advantage be brought from a distance is now pretty generally allowed and practised, and as the subject becomes better understood, works of this character will be extended, but modern means and appliances in the use of bricks, tiles and the metals, should prevent any repetition of such works as the Croton aqueduct. In the Croton work, nothing has been learned or forgotten from the time of the Romans, every feature of it would have been equally well constructed 2000 years ago. It would be difficult to devise a more expensive work: to cross valleys, or where the natural surface of the ground falls below the plane of grade. The aqueduct is supported upon a foundation wall of stone, forming a solid wall or pier, 17 feet thick, varying in height to suit the natural contour of the valley, and the plane of the aqueduct; placed upon such wall or pier, the true aqueduct or water-way is constructed with a brick-lining upon a concrete foundation; the side walls are backed up with rubble masonry. The whole structure thus formed is banked up with earth on each side, trimmed off to a side slope of one

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to one, the surface of the embankment being paved with rubble. The sectional area of the water-way is in some instances about one-thirtieth that of the whole work, including pier and embankment. On portions of the line, as at Sing-Sing, the Mill River, Jewell's Brook, Hastings, at Jonkers, Clendinning Valley, and other places, masonry structures of the most expensive character have been constructed; but, nevertheless, in several instances it has been found necessary to line the water-way with iron; this is the case over the Clendinning Valley, and at Sing-Sing Kill. At the Harlem River and Manhattan Valley two cast-iron pipes, of 3 feet interior diameter, descend into, and crossing both valleys, delivering the water into the masonry aqueduct on the opposite side. The cost of the Croton Aqueduct may be contrasted with the following table:—

Cost of Canals in England.

Canals, including Land, have cost per mile as under:—

	Length, in Miles.	Total Cost.	Cost per Mile.
		£.	£.
The Rochdale Canal . .	21½	291,900	13,900
The Ellesmere Canal . .	57	400,000	7,017
The Kennet and Avon .	78	420,000	5,384
The Grand Junction . .	90	500,000	5,555
The Leeds and Liverpool .	129	800,000	6,201
The Clyde Canal . . .	35	200,000	5,714
Total . . .	410½	2,611,900	About 6,370
The Croton Aqueduct .	38¼	2,500,000	About 71,000

Note.—The Rochdale Canal traverses a most difficult country: bridges and locks are numerous. The Grand Junction Canal passes more than once the great ridge of hills that divide the waters of England. The Forth and Clyde Canal, in Scotland rises and falls 160 feet vertical, by means of 39 locks: it is 8 feet deep of water, and passes vessels 19 feet wide.

The average cost of these canals is, it will be seen, many times less than the cost of the Croton aqueduct. The canals have, however, for the most part an open channel of earth-work, but there are numerous bridges, culverts, embankments, tunnels, aqueducts, and locks, some of which works are of a heavy and expensive character.

The question of construction with respect to the New York aqueduct, was, it appears, discussed at the outset, and to quote from a description of the work, "The following modes were presented: a plain channel formed of earth, like the ordinary construction of a canal feeder; an open channel, protected against the action of the current by masonry; an arched culvert or conduit, composed essentially of masonry; or iron pipes. An open canal was objected to, on account of exposure to impurities from surface washings, and liability to stoppage from frost; an open channel of masonry had the same objections made to it; and a continuous line of iron pipes was rejected, because of the vertical undulations, which would offer so much resistance to the flow of water that the discharge would be diminished in a very great degree." This could hardly be considered, by any person fully acquainted with the principles of hydraulics, a valid reason at that time, and most certainly

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is not so now; air valves on the upper bends would have been a security for the due action of the pipes; but the difficulty is not worth reasoning out. The New York engineer has been smitten with the works of Egypt and Rome to such an extent, that nothing less than a work equal or superior in massive grandeur would serve for modern use. Like many later works, in this country, railway works for instance, appearance and personal fame have been more considered than true economy. This was not the case with our most celebrated canal engineers, who studied practical utility in conjunction with strict economy, and they produced works equal to the requirements of the time and age, at a minimum cost.

The use of iron, wrought and cast, may be much more extensively employed in water-works than has hitherto been the practice; and, each placed where their capabilities may be best used, works of equal grandeur and magnificence to any of modern or even ancient times, may be constructed for a first cost many times less. Where it is not thought advisable to cross a valley or river by an inverted syphon-pipe, an elevated wrought-iron tube-aqueduct may be constructed, light, elegant, nay, even graceful in structure, and which shall be capable of carrying a volume of water equal to that brought by several of the Roman aqueducts combined. Telford set an example in his celebrated Pont-y-Cyssylte Aqueduct, which is 126 feet in height, 1,007 feet in length, and has a cast-iron water-way as sound and perfect now as the day it was made. For the purposes of a water-supply merely, this aqueduct might now be constructed at the same elevation, to carry the same volume of water (namely, about 20 millions of gallons daily), at one-fourth the cost; as two-thirds of the present piers might be dispensed with. In July 1846, I proposed a plan to the corporation of Liverpool, to bring in a supply of water from the river Dee, known by the name of the Bala Lake Water-works scheme, as the Dee rises in that lake. It was however proposed to take the water at a point of the river three miles above Llangollen, about 325 feet above low-water level at Liverpool. The whole length of the aqueduct would have been 64 miles, but for 40 miles the upper edge of the valley of the Dee would have been contoured, and in no district could land more favourable for a work of this class be found. The several intermediate valleys would have been crossed with inverted syphons, or by means of elevated aqueducts of wrought iron. The plans for which were submitted to Mr. Fairbairn, who reported as follows:—

"*To the Chairman of the Water-works Committee, Liverpool.*

"Sir, *Manchester, October* 1846.

"Mr. Rawlinson has submitted to my inspection drawings for sheet-iron aqueducts for conveying water across the Weaver, and other valleys from the river Dee to Liverpool.

"In forming an opinion upon this project, several considerations present themselves: 1st, security; 2nd, durability; 3rd, as to the comparative expense between this mode and inverted syphon-pipes; 4th, atmospheric effects, or the changes to which the iron aqueduct would be subjected during the extremes of temperature at different periods of the year; and lastly, the effects of high winds.

"With regard to the first, I would observe, that rectangular troughs,

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or, rather, tubes, 6 feet deep and 2 feet wide, with close tops, can be made of sufficient strength to carry 33 tons of water on 100 feet span, and equal to 12 square feet of area: the weight of 100 feet of such a tube will be about 12½ tons.

"2nd. Durability. In this respect, care must be taken to prevent oxidation, and in order to do this effectually, it will be necessary to make the top of the tubes, as all the other parts, perfectly water-tight, and the tube being always full of water, it will be a great security against corrosive action in the interior. On the outside, the usual preservatives must be applied; with these precautions, the tubes might last for an almost indefinite period of time.

"3rd. The expense of the iron portion of the aqueduct will be about 20,800*l.* a-mile; that is, computing the tubes and erections at 32*l.** per ton, or about 400*l.* for 34 yards. In this estimate I have not included the cost of the masonry, which I have left in the hands of the engineer.

"4th. The effects of winter, or the change of temperature, will not be severely felt on a long and somewhat flexible tube. Internally, the temperature will not vary considerably, as it never can be above 60°, and never lower than 32°; and any expansion or contraction from that cause will not seriously affect the stability of the tube.

"Lastly. The effects of high winds will not in any way endanger the security of the structure; as, taking the lateral pressure at 50 lbs. upon the square foot, the whole lateral pressure will not exceed 13¼ tons.

"Now the weight of the tube, and the water it contains, will be 45½ tons; consequently, the vertical will be to the horizontal pressure as 3½ to 1 nearly, exclusive of the lateral strength of the tube.

"Altogether, and under all the circumstances, there is no difficulty in conveying the water in the way proposed, provided that necessary attention be paid to the erection of the piers and the construction of the tubes.

"I am, Sir,

"Your faithful obedient servant,

"W. FAIRBAIRN."

The district drained by the Dee above the proposed junction of aqueduct is of vast extent; 289 square miles; and the volume of water poured down the river at the same point equals 365,000 millions of gallons annually, or an average of 1,000 million gallons each 24 hours. Geologically, the district is most favourable, as the rocks are principally clay-slate, and the water seldom exceeds one degree of hardness. The estimated cost to deliver 30 millions of gallons daily in Liverpool was a little under 600,000*l.*

The extent and character of the Roman aqueducts are tolerably well understood, though there is some dispute amongst antiquarians as to the number which actually entered Rome; according to some authorities (P. Victor), there were 20. Their united volume of water is said to have exceeded 500 millions of gallons of water daily (it is set down for nine of them at 376,834,379 gallons daily). "Some of these aqueducts brought water to Rome from more than a distance of 60 miles, through rocks and mountains and over valleys; supported on arches in some places above 100 feet high, one row being placed above another."

* Wrought iron structures could now be manufactured for a price much less than the one named here.

The care of the aqueducts under the emperors was entrusted to certain officers, called *Curatores aquarum*, with 720 men, paid out of the public funds, to keep them in repair. The declivity of an aqueduct was at least the fourth of an inch every 100 feet; where the water was conveyed under ground, openings to the air were formed every 240 feet. Mr. Rawlinson.

The aqueduct of Spoletto, in Italy, is one of the finest structures ever erected by man; it is 420 feet high; the middle arch is 328 feet in clear height, supported on piers 10 feet 6 inches thick. Modern engineers may learn how to economize materials by a study of this structure. The main piers of Telford's otherwise beautiful bridge at Bangor, and the aqueduct at Pont-y-Cysylte, are clumsy and massive in comparison. The piers and land abutments at the Britannia Bridge, spanning the same straits, are most extravagantly costly and ponderous, contrasted with the aqueduct of Spoletto, or with the work they have to perform.

If modern science has taught us how to make a steam-engine, it has not yet fully inculcated the necessity there is that rigid economy should be studied in all engineering works. This, however, must be applied in an especial degree to all works connected with towns' improvements, namely, drainage and water supplies. If 20 houses can be perfectly drained and supplied with water for the cost hitherto charged upon one, and the work much better done, it is the duty of all concerned to see that so desirable a work is accomplished. In laying out new works, due regard must be had to efficiency, as to economy, and it must ever be considered that there may be many degrees of cost up to an extreme maximum estimate, but there is only one minimum; and it will require constant attention, labour, and care, to secure this. Incompetency is adequate to any of the first; knowledge and judgment, with care, are requisite to secure the latter.

STATEMENT of the ESTIMATED COST of PUMPING, for continuous discharge, the SEWAGE—including the soil-water and the greater proportion of the rainfall—of the SURREY and KENT District of the Metropolis.

THE flat district of London on the Surrey and Kent side of the river is of very considerable extent, but its boundaries are not clearly defined. For the present purpose its area may be roughly estimated at 4,000 acres, the number of its houses at 80,000, and of its population at 500,000. It may be considered as forming about one-fourth part of the whole metropolis. Mr. Rammell.

This district being placed in great part on the level, or but just above, or below, the level, of high-water; is for many hours every day, all drainage from it by natural means, is stopped by a natural obstacle, the rising and falling river. In order, therefore, to relieve it from accumulations of house sewage and rainfall, when the outfalls are thus closed, it would be necessary to raise by artificial means these liquids above the level of the tide.

On the present system of intermittent drainage they are ponded up at such times in huge sewers, where, in a state of repose, their power of holding heavier matter in suspension being lost, the grosser and more offensive particles contained in them are deposited, to the manifest deterioration of the healthful condition of the district.

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Steam is the most economical power that could be employed to raise the refuse for continuous discharge; and it is beyond question as fully applicable to the purpose of town relief from sewage accumulations as to that of town supply with pure water.

By pumping to the requisite height the discharge may be effected at any point, however distant; the height, of course, increasing accordingly as the outfall is more removed. Thus for discharge into the river at the most convenient and least objectionable point of the shore line of the district, say at Deptford, the sewage would have to be raised a certain number of feet; for discharge at Woolwich, a few feet higher; at Erith, a few feet higher still.

It appears that the length of the tidal flow of the Thames is about seven miles, and that of its ebb about ten miles. Sewage matter, therefore, discharged at low water at Deptford would be carried up by the returning tide as far as Vauxhall Bridge; at Woolwich, to near the Thames Tunnel; at Erith, to near Woolwich.

In the first supposed case, the pollution of the river from this source would extend along the whole of its course through the more thickly-built part of London; in the second, the pollution would reach far into the densely peopled quarters; in the last, no particle of the sewage would ever be carried above the lowest suburb—Woolwich.

The expense of pumping will, of course, bear a proportion to the height to which the sewage is to be raised; but it will not increase in an equal ratio.

Besides the greater expenditure for pumping in order to effect the discharge at Woolwich or Erith, instead of Deptford; a sum would have to be allowed for the pipeage requisite to convey the sewage to those places respectively.

The Board having requested me to furnish an estimate of the expense of relieving the district in question by pumping, I propose now to calculate, upon certain assumed data, what it would amount to in each of the three supposed cases of discharge, viz., 1, at Deptford; 2, at Woolwich; 3, at Erith.

The following data are assumed:—

(*a.*) That the height to which the sewage would have to be raised for discharge at Deptford would be 20 feet.

(*b.*) That for discharge at any lower point of the river this height would increase in the proportion of 12 inches for every mile of distance. (This would give a rate of fall for the outfall pipe of 12 inches per mile in addition to the fall of the river.)

(*c.*) That the cost of the outfall pipe would be 10,000*l.* per mile.

(*d.*) That the quantity of house sewage to be raised would be in the proportion of 20 gallons daily to every inhabitant.

(*e.*) That of the total rainfall of the district 24 inches would have to be raised.

(*f.*) That engine power capable of effecting the continuous discharge of the entire daily quantity of sewage (exclusive of rainfall) in the space of six hours would have to be provided.

The three following tables show the estimated annual expense of pumping for discharge at the three places respectively:—

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TABLE I.

ESTIMATE of the ANNUAL EXPENSE of PUMPING by Steam Power the SEWAGE of the SURREY and KENT District, 20 feet high, for discharge at DEPTFORD.

Capital.

	£.
Two Cornish engines (duplicates) of 175-horse power each, at 55*l.* per horse	19,250
Engine-house (say)	7,000
Land for ditto (say)	1,000
Total capital	£27,250

Annual Expenses.

Interest on Capital, Depreciation, and Repairs.	£.	s.	d.	£.	s.	d.	£.	s.	d
To interest on 27,250*l.*, at 5 per cent.				1,362	10	0			
To depreciation on 26,250*l.*, at 2½ per cent.				656	5	0			
To repairs on 26,250*l.*, at 2½ per cent.				656	5	0	2,675	0	0
Working Expenses.									
To 960 tons of small coal, at 12*s.*				576	0	0			
To oil, hemp, tallow, &c., at 5*s.* a-day				91	5	0			
To wages—Engineer, 5*s.* 6*d.* a-day	£100	7	6						
„ Stoker, 4*s.* 6*d.* a-day	82	2	6						
„ Labourer, 3*s.* a-day	54	15	0						
„ Manager, 3*l.* a-week	156	0	0	393	5	0	1,060	10	0
Additional, for Pumping Rainfall (annual depth 2 feet).									
To 375 tons of small coal, at 12*s.*				225	0	0			
To extra labour over regular working hours				150	0	0	375	0	0
Total annual expense of pumping sewage for discharge at Deptford							£ 4,110	10	0

TABLE II.

ESTIMATE for PUMPING the same, 25 feet 6 inches high, for discharge at WOOLWICH.

Capital.

	£.
Two Cornish engines (duplicates) of 218-horse power each, at 53*l.* 15*s.* per horse	23,425
Engine-house (say)	7,500
Land for ditto (say)	1,000
Total capital	£31,925

Annual Expenses.

Interest on Capital, Depreciation, and Repairs.	£.	s.	d.	£.	s.	d.	£.	s.	d.
To interest on 31,925*l.*, at 5 per cent.				1,596	5	0			
To depreciation on 30,925*l.*, at 2½ per cent.				773	2	6			
To repairs on 30,925*l.*, at 2½ per cent.				773	2	6	3,142	10	0
Working Expenses.									
To 1,165 tons of small coal, at 12*s.*				699	0	0			
To oil, tallow, hemp, &c., at 5*s.* 6*d.* a-day				100	7	6			
To wages—Engineer, 5*s.* 6*d.* a-day	£100	7	6						
„ Stoker, 4*s.* 6*d.* a-day	82	2	6						
„ Labourer, 3*s.* a-day	54	15	0						
„ Manager, 3*l.* a-week	156	0	0	393	5	0	1,192	12	6
Carried forward							£4,335	2	6

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		£.	s.	d.
Brought forward		4,335	2	6

Additional, for Pumping Rainfall (annual depth 2 feet).

				£.	s.	d.
To 478 tons of small coal, at 12*s*.	286	16	0			
To extra labour over regular working hours	150	0	0			
				436	16	0
Total annual working expenses, exclusive of outfall pipe				4,771	18	6
Add interest at 5 per cent. upon capital (55,000*l.*) sunk in 5½ miles of outfall pipe				2,750	0	0
Total annual expense of pumping sewage, and discharging it at Woolwich				£7,521	18	6

TABLE III.

Estimate for Pumping the same, 31 feet high, for discharge at Erith.

Capital.

	£.
Two Cornish engines (duplicates) of 260-horse power each, at 52*l.* 10*s.* per horse	27,300
Engine-house (say)	8,000
Land for ditto (say)	1,000
Total capital	£36,300

Annual Expenses.

Interest on Capital, Depreciation, and Repairs.				£.	s.	d.	£.	s.	d.
To interest on 36,300*l.*, at 5 per cent.				1,815	0	0			
To depreciation on 35,300*l.*, at 2½ per cent.				882	10	0			
To repairs on 35,300*l.*, at 2½ per cent.				882	10	0			
							3,580	0	0
Working Expenses.									
To 1,370 tons of small coal, at 12*s*.				822	0	0			
To oil, tallow, hemp, &c., at 6*s*. a-day				109	10	0			
To wages—Engineer, 5*s*. 6*d*. a-day	£100	7	6						
,, Stoker, 4*s*. 6*d*. a-day	82	2	6						
,, Labourer, 3*s*. a-day	54	15	0						
,, Manager, 3*l*. a-week	156	0	0						
				393	5	0			
							1,321	15	0

Additional, for Pumping Rainfall (annual depth 2 feet).

				£.	s.	d.
To 580 tons of small coal, at 12*s*.	348	0	0			
To extra labour over regular working hours	150	0	0			
				498	0	0
Total annual expenses, exclusive of outfall pipe				5,402	15	0
Add interest at 5 per cent., upon capital (110,000*l.*) sunk in 11 miles of outfall pipe				5,500	0	0
Total annual expense of pumping sewage, and discharging it at Erith				£10,902	15	0

Note.—In each of the three cases given, one of the engines would raise, at ordinary working, the total daily quantity (10,000,000 gallons) of sewage in six hours. Upon emergencies the full power of both engines would raise as fast as produced, and in addition to the house sewage, a rainfall equal to a depth of $\frac{2}{10}$ths inches (nearly) in six hours over the entire area; and exclusive of the house sewage, a rainfall equal to a depth of $\frac{3}{10}$ths inches (nearly) in six hours.

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From the foregoing tables it follows that the expense of pumping and providing for the discharge of the sewage (including two feet depth of rainfall) of the district, would be met by an annual charge per house and per inhabitant as follows:—

If spread over the district, and discharged at Deptford, per house 1*s.* 0½*d.* (12·33*d.*), per inhabitant 2*d.* (1·97*d.*); discharged at Woolwich, per house 1*s.* 10¾*d.* (22·56*d.*), per inhabitant 3¾*d.* (3·61*d.*); discharged at Erith, per house 2*s.* 8¾*d.* (32·71*d.*), per inhabitant, 5¼*d.* (5·23*d.*)

If spread over the entire metropolis, and discharged at Deptford, per house 3¼*d.*, per inhabitant 0½*d.*; discharged at Woolwich, per house 5¾*d.* (5·67*d.*), per inhabitant, 1*d.* (0·90*d.*); discharged at Erith, per house 8¼*d.* (8·21*d.*), per inhabitant 1½*d.* (1·31*d.*)

T. Webster Rammell.

London, May 1850.

Mr. Samuel Hocking, Civil Engineer, examined.

Mr. Hocking.

1. Are you not particularly engaged in the supply of Cornish engines?—I am.

2. Have you not supplied these engines in various parts of the country?—I have.

3. In some evidence as to the working of a Cornish engine in the metropolis of an 80-inch cylinder, given in the year 1844, it was stated, that with coal at the price of 12*s.* the duty done by the engine at that period was the raising of 80,000 gallons of water 100 feet for 1*s.* What would such an engine do now?—Since that period I have, as an engineer and agent to the firm of Sandys, Vivian and Co, Hayle, Cornwall (where these engines are made), erected some engines of larger size, which, principally from their increased size, enable us to pump water at a still cheaper rate. Supposing one of these engines constantly at work night and day, and at a moderate speed, it would raise, on an average, 87,000 gallons of water 100 feet high for 1*s.*

4. That is to say 388 tons of water?—Yes, 388½ tons of water lifted 100 feet high for 1*s.*

5. What is the size of that cylinder?—90 inches in diameter.

6. What number of horse-power according to the usual reckoning?—About 230 horse-power.

7. Was that in London?—Yes.

8. And what price do you calculate the coals then to have been?—12*s.* per ton for Newcastle small coals.

9. Supposing the supply for the Metropolis to be taken at 50,000,000 gallons a-day, to be lifted 100 feet high, how much would the average cost of pumping that quantity be?—28*l.* 14*s.* 8*d.* with engines of the largest size.

10. What would the supply per house be during the year, taking it at 75 gallons per diem?—27,375 gallons, or in round numbers 28,000 gallons.

11. What would be the annual cost of pumping 75 gallons per house per diem?—About 3·8*d.* or under *fourpence.*

12. Do you happen to know whether 100 feet would be a fair lift for the Metropolis?—It would be sufficient for some districts. But

Mr. Hocking. the height to which the water must be pumped will depend on the elevation of the district and its distance from the engine-station. At one of the Water Works I know it is pumped to more than double that height.

13. Of course the smaller sized engines will not work to the same advantage as the larger ones?—The amount of labour is greater in proportion to the power employed, and the consumption of coals is also in an increased ratio.

14. Will you put in a scale of the actual survey of engines of the different sizes you have made?—The following table was put in by the witness:—

Cost of Pumping Water for the Supply of Towns by Cornish Engines of various sizes, using Newcastle small Coals at 12*s.* per Ton.

Size of Engine in Horses Power.	Quantity of Water raised to 100 feet high for One Shiling.	Annual cost per House, with a supply of 75 Gallons per Day.
H.P.	Gallons.	Pence.
230	87,997	3·73
180	80,436	4·08
135	74,862	4·38
100	67,848	4·84
65	61,549	5·33
40	54,905	5·98
25	43,214	7·60

N.B.—This Estimate does not include interest on outlay or the Repairs.

15. What is the size of the smallest?—A 30-inch cylinder about 25 horse-power.

16. How much more expensively would such an engine work in proportion than that of the 230 horse-power. Will you show it by a proportionate table of the whole?—About double the expense as shown in the table above. By an engine of 25 horse-power, 43,000 gallons only can be pumped 100 feet high for 1*s.*, whereas by the 230 horse-power engine, 87,000 gallons can be raised to that elevation at the same cost.

17. Then a single engine of about 25 horse-power for a single house instead of pumping the required quantity for 4*d.* would only do it for about double that sum?—It would be somewhat under 7¾*d* if done by the smallest engine.

18. That is the working expense, the interest of capital being omitted?—Yes.

19. Then this would be the additional working expense of delivering water at the base and delivering it 100 feet high?—Yes.

20. Supposing you had to pump the water to distribute it at the basement of the house, the cost of afterwards raising it 100 feet high would be what you have stated?—Yes.

21. What will any given quantity of coal converted into steam do in pumping by these engines?—A ton of coals will lift 1,600,000 (one million six hundred thousand) gallons 100 feet high.

22. Or, supposing a room filled with water 750 feet square, and

4 feet deep, what quantity of coal would it require to lift that water 100 feet high?—8 tons, 15 cwt., 3 qrs. If only 50 feet square it would be lifted with 87½ lbs. of coals. Mr. Hocking.

23. Is it not your practice in Cornwall to make it the stoker's or engine-man's interest to work the engines with the least quantity of fuel?—Yes. The coals are weighed out to each man and carefully registered against him; and if one does not make it do as much work as another, it is easily discovered.

24. And each man is promoted according to the work he does?—Yes.

25. Then you are enabled to register the power according to the work done?—Yes; it is registered and marked down according to the number of strokes made by the engine.

26. What is the quantity of coal consumed in these engines compared with others?—About one-third.

27. Is there any peculiarity in the kind of coal that it is necessary to use for these Cornish engines?—No.

28. Then in fact when we see a Cornish engine giving out little or no smoke, it is because the consumption of coal is the more complete? —Yes. In Cornwall, however, the coal used is from Swansea, and it gives off less smoke than the Newcastle coal.

29. How is it with Newcastle coal when used in Cornish engines? —The quantity of coal consumed is not more than one-third of the quantity used in other engines; and by having much more boiler surface in proportion to the quantity of coal consumed, and a very weak current of draft through the flues, the smoke remains longer over the fire and more of it is consumed.

30. Then the use of Cornish engine involves a saving of two-thirds of the coal, and a consequent dimunition of two-thirds of the smoke?—Yes; even to a greater extent than that, probaby one-sixth part of the smoke given off by ordinary engines would be nearer the truth.

31. With 100 horse-power Cornish engine, what would be the saving of coals per diem, calculating the coal to be respectively at 5*s*., 8*s*., 10*s*., 12*s*., and the London price 1*l*. per ton?—

	£.	*s*.	*d*.
Coal at 5*s*. per ton, the saving per day would be	1	16	0
,, 8*s*. ,, ,, ,,	2	17	0
,, 10*s*. ,, ,, ,,	3	12	0
,, 12*s*. ,, ,, ,,	4	6	0
,, 20*s*. ,, ,, ,,	6	12	0

Annual saving at the present price of small coals in London (12*s*. per ton) and working six days per week, would be on 100 horse-power engine no less a sum than 1,345*l*. And for one of the largest engines the saving would be, per day, 7*l*. 11*s*., or per annum, 2,363*l*., which would represent a capital (at 5 per cent. interest) of 47,260*l*.

32. Also make the same comparison with a 25 horse-power Cornish engine?—

	£.	*s*.	*d*.
Coal at 5*s*. per ton, the saving per day would be	0	11	6
,, 8*s*. ,, ,, ,,	0	18	6
,, 10*s*. ,, ,, ,,	1	3	0
,, 12*s*. ,, ,, ,,	1	8	0
,, 20*s*. ,, ,, ,,	2	2	0

Mr. Hocking. 33. Also the actual annual expense of working different sized engines, say a 200 horse-power, a 100, a 50, a 25, and a 10 horse-power engine?—I keep no account of "the actual annual expense of working" the engines which I supply, as they are worked at the expense of the Water Companies, and are entirely under the control and management of their engineers.

34. What are the prices of the different sized engines, and what would be the annual working expense of them, the original outlay, and a fair allowance for annual depreciation?—The cost of these engines will depend on circumstances, which are found to differ in almost every case. Engines of the largest size will cost, when set to work complete, about 50*l.* per horse-power, the smaller one somewhat more. The "allowance for annual depreciation" of the Cornish engines employed at Water Works will, in no case, exceed the amount allowed for that of the ordinary engines working under the most favourable circumstances. I know of no accident happening to them since their first introduction to Water Works, about 12 years ago, whilst their repairs have been of a very trifling and inexpensive kind.

Joseph Quick, Esq., examined.

Mr. Quick. 1. Are you not engineer to the Southwark and Vauxhall Company and consulting engineer to the Grand Junction Company?—Yes, I am.

2. What quantity of water is pumped per diem by the Grand Junction Company?—Between three and four millions of gallons, or an average daily supply throughout the year of 3,541,716 gallons.

3. To how many houses or buildings?—14,058.

4. What do you estimate the average quantity delivered per diem to each house in this district?—The average daily supply for domestic use in the past year has been 223 gallons per house, or 25 gallons per head; or, for all purposes, including road-watering, railways, &c., 252 gallons per house, or 28 gallons per head.

5. By a former Return it was stated that the delivery in the district of the Grand Junction Company was upwards of 300 gallons; has the quantity been decreased?—I think there must have been some inaccuracy in that return, partly perhaps arising from the supply being then only given three days in the week, and partly from a less perfect arrangement of mains and stop-cocks: there has also been since a more exact account taken of the number of separate tenements.

6. What is the quantity pumped per diem by the Southwark and Vauxhall Company?—Between six and seven millions of gallons, or a daily average throughout the year of 6,011,225 gallons.

7. To how many separate houses and buildings?—35,511.

8. What do you estimate as the average quantity delivered to each house or building per diem?—143 gallons daily throughout the year for domestic use, being 22 gallons per head; or 169 gallons, which includes the supplies to railways, manufactories, road-watering, &c., being 26 gallons per head.

9. Are not the houses on the south side, or in the Southwark and Vauxhall district, (on the average) of a much lower class in rental and condition than those of the Grand Junction?—Certainly, very greatly so; but it is difficult to draw a comparison between the districts.

10. In what way may the Commissioners least inconveniently to the Companies verify the fact as to the quantity of water daily distributed by them to their tenantry in each district?— Mr. Quick.

" *Waterworks, Sumner-street,*
" *December* 20, 1849.

" Sir,

" I beg to lay before you the following instructions for the purpose of ascertaining and verifying the quantity of water pumped by the London Water Companies and supplied to their tenantry in the past year.

" 1st. To take an account from the engine-book of the number of strokes of each engine (each engine being named or numbered), and to measure the capacity of the pumps, to ascertain the quantity of water delivered.

" 2ndly. To appoint some engineer to visit each of the Waterworks establishments, to take the counters of the engine for a given time, and also to gauge the pumps for the delivery.

" I am, Sir,
" Your obedient servant,
(Signed) " J. Quick."

11. Do you know the average size of butts and cisterns to the lower class of dwellings?—They are very various; ranging from a small pork-tierce of three or four gallons, to an 18, 54, or 63 gallon cask, but seldom approaching to the latter. Cisterns are very rare in small houses, and when put up do not contain more than 40 to 50 gallons.

12. Are not butts of the size of 100 gallons very rare in the Southwark district?—Yes; there are very few of the smaller class of six or eight roomed houses that have above a 63-gallon cask; but houses of a better description will have receptacles that contain between 100 and 200 gallons.

13. Have you ever had an opportunity of gauging the contents of butts, and the quantities of water consumed?—I have lately made some experiments, and find that the butts of four, six, and eight roomed houses, containing 40, 50, and 63 gallons respectively, are, on the average, about half emptied in a day; so that when the water is turned on only half a butt would be required by 19 out of 20 houses; but it generally happens that the twentieth is a baker or butcher, or perhaps a public-house, with a butt or cistern in an elevated position, for the convenience of his business or the saving of room; and to satisfy the wants of this one tenant the water has to be kept on three or four times longer than would be sufficient for the ordinary supply; and the waste going on the whole time from the adjoining houses, brings up the average daily supply to 143 gallons for each house.

14. Then you think that the butts served them well, as far as your observation went, when the supply was given on alternate days?—Yes; but not so well as now, with the exception of the very poorest districts, in which, when the Company supplied on alternate days, butts were provided; but since the water has been turned on at a certain hour every day in the week, many take their chance of filling any vessel they may possess during the time it is on. The daily supply has been afforded by the Company for nearly two years.

15. Has your number of customers increased in a greater ratio

Mr. Quick. since the daily supply has been given?—Not more than previously, as the same amount of water in the aggregate was allowed to each house as at the present time; the only difference being that it is now turned on for one hour daily, in place of two hours every other day.

16. Have you seen a set of gaugings made on a block of 1300 houses, on the north side of the Thames, which were supplied with water, and where it was proved that the quantity of water daily consumed from the cisterns was 51 gallons per house?—I have; and I believe that quantity to be a fair average of the positive consumption for the middling classes of houses, and it quite accords with my own observation.

17. In that particular case, and in others also, the general conclusion has been stated, that the quantity of water wasted is absolutely three times greater than the water consumed?—I believe that to be the case; generally I know it to be so in the Southwark and Vauxhall district.

18. Then the only difference is, that on the north side the water is silently conducted through a waste-pipe from the cistern to a drain, and on the south side is allowed to run over the sides of a butt and saturate the earth?—Yes, and in many cases it causes the most serious inconvenience to persons situated on lower levels than their neighbours, by flooding them every time the water is turned on, and it is one of the arrangements that would require the most serious consideration in any new system of supply.

19. Mr. Roe stated that, on an average, the supply did not exceed 76 gallons for the highest class of houses, even where there are three water-closets and baths?—I believe that if you were to take the average of a number of houses in any district, 76 gallons would be found sufficient, but I am disposed to think houses having three water-closets and baths would in most cases be found to consume a much larger quantity.

20. Have you observed the house-drains in action with this intermittent supply?—I have frequently.

21. What was their state, notwithstanding this waste of water?—In many instances they were filled up with black matter; they had gone on for years, until a final stoppage took place.

22. Then from the construction of house drainage, according to your experience as an engineer, you corroborate the opinion that the deposit was not removed by the flow of water on the days of supply, but went on increasing until it was removed by hand-labour?—Yes.

23. And you agree that the common estimate of water-supply is greatly in excess?—Greatly.

24. Does your own experience corroborate the statements of the fact that in butts and cisterns the water in a close atmosphere becomes tainted?—All waters are liable to become tainted in an impure atmosphere, but where the butts or cisterns are properly situated and attended to, the water will keep pure for a great length of time.

25. Have you examined the system of constant supply as it is carried out in Preston?—I have.

26. Are the houses there, occupied by the labouring classes, on the whole of a better description than those occupied by the labouring classes in Lambeth and a large portion of Southwark?—Yes, both as to size and convenience; they are mostly provided with washhouses and sinks, and all the conveniences necessary for the comfort of a family.

27. The manager of the works in Preston stated in evidence that their average supply to 6000 tenements was about 50 gallons per house per diem?—I have no doubt, from the great care that is taken to prevent waste, that the quantity named is correct. Mr. Quick.

28. There is a large proportion of manufactories included in that average of supply?—I wsa informed that was the average daily quantity used for all purposes of consumption, and that it was found to be sufficient for a population having larger demands for water than an average one.

29. Did you examine any other works than those at Preston where the system of constant supply had been in action?—Yes, at Nottingham, where I questioned several of the housekeepers (both in the higher and lower portions of the town), to see if they were inconvenienced by the water being turned off at any time; I was informed that, before the water is turned off, a notice is sent from the Water Company to each tenant, with an intimation that the supply will be stopped from a certain time to a certain time. They know accordingly what quantity of water to draw off before the main is shut; but this happens so seldom, that they think nothing of it.

30. What is the smallest size main-pipe you know to have been used for the service of mains?—The smallest lead pipe for the service of a number of houses was a 1-inch pipe; it was the entire side of a long street of some 35 or 40 houses.

31. Under what head of pressure?—I only know that in the middle of the day we went to the last house. We examined and asked the person whether the water was on, and we were told it was never off. That was a house at the highest end of the street, and the flow was very free from a half-inch pipe.

32. Has there been an instance of constant supply put on in London for tenements occupied by the poorer classes?—Yes, on a small scale, in Rose-court, Dockhead; and a small part of Jacob's Island, Bermondsey. The agent to Rose-court applied to the Company to ascertain the best means of improving the supply to his tenements, and at the same time get rid of the nuisance of a common tap, which was running for two or three hours every day, and causing perpetual quarrels between his tenants and the people from Jacob's Island, who had not any supply from the Company. It was recommended to take away the common tap and erect a tank in some central situation, and lay an inch lead pipe with a half-inch branch to each house. This has been done, and the result has been a marked improvement in the people; as they now pay their rents regularly, being fearful that they would not find the same accommodation if they were to go to other houses; and the agent informed me that he was so well satisfied with the arrangements, that he would have the whole of the houses under his care laid on in the same way. The Company have also been gainers, as they save at least 200 or 300 gallons of water daily. The other supply is to 10 houses on a part of Jacob's Island, from a tank and an inch lead pipe with a half-inch branch leading into each house; the same result as regards the tenants has taken place in this case.

33. And you advise then, as the preventive for this disorder, that a constant supply should be laid on from one general reservoir or tank to small houses?—I believe that would be the most efficient way of affording a constant supply to large blocks of small houses, and it

Mr. Quick. could be arranged very economically by persons availing themselves of the use of the Company's pipes beyond the branch leading into the tank as a feeder to the house services. It would also be a great protection to the high-service of the district, as all the water must ascend to the height of the tank before it could be drawn off; and if the Company's pipes could not be used to conduct the water, a small service of 1-inch or more in diameter, leading from the tank with ½-inch branches to the houses, could be laid in the most convenient situation, and would be the least expensive mode of giving a supply to houses that are not at present laid on.

34. Will you state the result of the experiment as to the comfort of the people?—The difference is very great; the agent to the estate informs me that quarrelling has scarcely been known among his tenants since the alteration, that the tenants never refuse to pay him the rent, and that he could obtain 3*d*. or 6*d*. per week more for each house, if any of them became empty; and if he had 100 houses in the neighbourhood, with water laid on in the same way, he could find tenants for them at increased rents.

35. And the great waste must have saturated the ground and caused much dampness in the neighbourhood?—Yes, and the paving-stones were often washed up and the inside of the houses made very damp. The tank holds about 210 gallons, and provides an ample supply for 10 small houses, at about 20 gallons per diem for each house. The tank is filled every day.

36. With an average population then that is enough?—On an average it is as much as is consumed in houses of that class—four-roomed houses.

37. From this case you may assume that the benefit might be extended to a larger class of houses?—Yes, to all, not only with advantage to the people themselves, but the Company also.

38. What do you apprehend would be the difficulties of changing the system from an intermittent to a constant supply?—The greatest difficulty would arise from the very defective state of the house service-pipes in poor districts, and the waste-pipes of cisterns in the better class of houses; also in making provision for supplying large manufacturers, road-watering, &c., at low levels at the same time that supplies would be required from services in the highest situations in the district. The first question would involve a remodelling of the lead service-pipes; and the second, a total change in the arrangements of the house cisterns, as I believe waste-pipes from cisterns would be fatal to any system of constant supply. The third could be arranged either by laying down a separate main, or by each manufacturer providing himself with a tank of sufficient capacity for his daily requirements, which could be filled at any convenient hour of the night; it would also be necessary to give the entire control over the lead service-pipes and everything connected with them to the Company, so that deficiency of supply, or waste of water, might at once be remedied by their servants and under the inspection of their officers.

39. It has been stated that smaller branch-pipes are used for the constant supply than for the intermittent one?—That I found to be the case at Preston and Nottingham, and I believe it would apply generally to supplies taken at nearly the same level.

40. How is it at Oldham, where water is delivered under 400 feet

pressure?—There, no doubt, the height would be great enough above the town to overcome the difficulties of the differences of height in it. Mr. Quick.

41. What is the proportion of breakages and other accidents to iron pipes?—Accidents seldom happen to the leading mains if properly laid, they are generally confined to the side services and small branch mains, and I believe they are caused by the vibration of heavy loads passing over them, and the sinking of the earth from defective sewers, &c. We find that one labourer is sufficient to make good all reparations required in each turncock's district.

42. What is the size of the districts?—Each turncock has to supply about 3000 houses and large consumers daily in the Southwark and Vauxhall district, and nearly 2000 houses in the Grand Junction district; the size depends upon whether it is in a crowded or suburban district. The Southwark and Vauxhall Company employ twelve turncocks, and the Grand Junction eight, each turncock being allowed one labourer. They are paid, according to their class, 18*s*., 20*s*., and 21*s*. per week. There is a great expense in paving, plumbing, &c.

43. With respect to the laying of pipes, are you able to distinguish any difference between the wear and tear of those laid in the front streets as compared with the wear and tear of those laid in the back streets?—A great deal will depend in all cases upon the way in which the pipes are laid; when experienced persons have been employed to carry out work of this description, little or no repairs are required, but if the pipes have been badly laid, they are a constant source of trouble and expense—they would be less liable to accident by being laid at the backs of houses.

44. Do you not think that the liability to accident would be greatly diminished by laying the pipes close to the houses?—Very much. We generally lay them, where practicable, within 2 or 3 feet of the kerbstone.

45. Has it not been found that house-drainage conducted at the backs of houses is more efficient and can be kept in repair at two-thirds less cost than when carried to the fronts?—Yes, it is better where convenient; but it is seldom that people will agree to have pipes or drains laid across their yards or gardens for the accommodation of their neighbours; and generally the property in any line of street is in the hands of so many different parties, that it has been found almost impossible to carry out any works of this description on a large scale.

46. But if it were a public regulation?—Then people would be glad to permit it.

47. Are there not frequent floodings from the breakage of the lead pipes passing under the houses?—Yes, and they would be avoided by having a small iron pipe laid along the backs of the houses.

48. Do you think that the expense of laying on a supply of water would be one-third less at the back of the houses than at the front?—Yes, particularly for small property; and there would be also the advantage of not having to cross areas; and, therefore, there would be less exposure to frost.

49. What depth is best for the sake of temperature?—The usual depth is 2 feet 6 inches below the surface; that is found to be sufficient to prevent the frost getting to the pipes.

50. You may be aware that it is stated to be important to get the

Mr. Quick. water delivered at a low temperature, particularly for water-closets, to check decomposition?—I believe it is so stated, and I should think that water travelling through a pipe at a mean depth of 3 feet (the average depth of the Water Companies' mains) have all the advantage of being kept cool in summer, and are sufficiently protected from frost in the winter.

51. You say upon your plan you would have a cistern for the constant supply of water; are you not aware of the objection to water standing in cisterns at all?—Yes, but the cisterns I have proposed for a system of constant supply are not to be used as reservoirs; they are merely intended to assist the general high service by preventing waste at low levels, and to act as safety valves to the lead pipes, which are generally manufactured of material too light to bear the pressure of the column of water which is acting on the leading and trunk mains, and they are, also, generally old and in a defective state.

52. In how many instances do you find the ball-cocks in action where cisterns and butts are in use?—The difficulty is in finding any, as in most cases the ball is taken off the cock and the water allowed to run down the waste-pipe into the drain or cesspool, saturating the ground and increasing the dampness of the neighbourhood.

53. Under the system you propose, of a small cistern with a hood, there would be comparatively small exposure to the atmosphere?—Very little or none. The action of the atmosphere would be very small indeed.

54. You have observed, doubtlessly, water in rooms to be in a very different state from that in which it has been delivered from the Water Company's service?—Very different, where exposed for any length of time to the tainted atmosphere of a crowded room, or stored in a foul vessel. But I have not observed any change take place in Thames water that has been properly filtered, and kept in butts or cisterns well situated. The water taken direct from the main is very pure, and quite fit for domestic use.

55. The water has been aërated in a comparatively pure district, compared with most of the districts to which it is supplied?—Certainly; and it is only in very unfavourable situations that the water is found to have the slightest tendency to become fetid.

56. Vitruvius says, that earthen pipes were used by the Romans at such heights as 100 feet; and instances have been adduced of Roman 3-inch pipes remaining even now at three or four times that height?—I have no doubt of it.

57. Have you laid any earthen pipes with a view of testing their strength?—Yes; and although the trials were not successful, I believe that with more perfect arrangements, and some alterations of the pipes, they might be used in suburban districts, and in small towns where there is not much heavy traffic to cause vibration.

58. We now see remains of considerable cities, and a system of earthen pipes laid down, apparently on a system of constant supply?—Yes; with cisterns or fountains.

59. Why should not the Roman system be carried out, with an increased purity of the water?—There is only one objection: if the water was very pure it would act on the present lead pipes; if it were 7, 8, or 10 degrees of hardness, it would not act on the lead.

60. Have you seen Mr. Austin's plan for the removal of sewer water; do you think there would be any probable obstructions in the pumping of such water?—None whatever, if precautions were taken to prevent quantities of straw or other floating matter accumulating in the pump-wells. I believe Mr. Austin provides against such obstructions by catch-gratings and other suitable arrangements. Mr. Quick.

61. Have you had brought under your notice experiments of street-washing by jets?—I have. I was present at experiments at Battersea regarding the force of jets of different forms for the distribution of water.

62. Then you have seen the report of Mr. Lovick on the washing of surfaces?—I have.

63. In respect to the rapidity of application, and the quantity of water used, do you concur in the result of the experiments stated?—Quite so. With a powerful jet, no doubt more work could be got over than with a jet at a low pressure.

64. With what power of jet would you work then?—All will depend on the size of the main, and the number of jets it would be necessary to have open at one time to get through the work; the fewer the jets and the shorter the hose the greater will be the power. There would be great difficulty in attaching any system of standpipes for street-watering to the present fire-plugs, and I believe it would be found necessary either to lay down a separate line of small pipes with proper stop-cocks and outlets, or transverse services from the present mains to the kerbstone with the same appliances.

65. Is a gallon per square yard a large average for washing?—After the first and second application I should think it was.

66. Have you seen the form of plug of the kind called Ghrime's plug? —I have not seen any plug that I think well adapted for this purpose; it ought to be something very strong and simple—easily repaired, and combining in itself the means of shutting off the water from the main, and attaching the hose-pipe with the common joining-screw.

67. Do you think that, with proper arrangements, these cleansings might be performed with rapidity by means of the jet, and with greater comfort than by any process of sweeping?—No doubt, if it could be done at convenient hours, and so as not to interfere with the house-service. In the constant supply, too many plugs opened in a low level would draw all the water from the upper levels and disturb the supply of an entire district, unless separate mains were laid for the purpose.

68. Does it consist with your observation that Mr. Lovick's estimate is a full one?—I think it is beyond an ordinary estimate.

69. Are you aware that at Philadelphia, where there is a constant supply, this system is in operation at a time when the servants are cleaning the door-ways, and yet is so managed that there is never any complaint of deficiency of supply?—I know that when we have a large fire we are obliged to shut off most of our services to compensate for the water flowing from the plugs at low levels, which generally interferes with the supply to the entire district.

70. Have you any means of regulating the supply to the demand?—The means of which we make use is to work the engines fast or slow so as to keep up the pressure in the mains to the height of the standpipes, and that is done by the engine-workers observing a mercurial gauge

Mr. Quick. attached to the trunk mains and fixed in the engine-house. The engine also itself strikes a bell, which instructs the men either to increase or diminish the speed, and this arrangement has been found to answer perfectly.

71. May we not expect great advantage from a constant supply of water, and the ready means of the application of it on emergencies?—No doubt of it, for half the large fires are occasioned by the immediate want of water to check them in their origin, and that causes them to become large fires.

72. There would be peculiar advantages in large candle and other factories?—Yes, and many railway stations have availed themselves of the Company's mains, by having a branch with joining screws taken into their premises, so that a hose-pipe can be attached and the water turned on immediately upon an alarm being given.

73. Would it not be one recommendation of street-washing that the hose would be at once prepared ready for immediate use, instead of having to send some distance for engines?—It would be important in all districts.

74. How many houses has each turncock?—About 3000; and each one has a labourer, who is employed in assisting and seeing to where pipes have burst or repairs are required.

75. Mr. Hawkesley states, that one man with a boy was able to keep the Nottingham water-works district in order?—That may be the case in a small district; we find that it takes on the average one turncock and one labourer to every 3000 tenants supplied. This number of attendants would no doubt be diminished under a system of constant supply, but I cannot say to what extent.

76. You have observed the sewer water; what was the state of the Thames water at the time they were pulling down London Bridge?—In the neighbourhood of their operations it was much more charged with heavy matter than ordinary sewer water from the disturbance of the chalk and rubbish which had been placed as a protection to the piers of the old bridge.

77. Do you feel any doubt as to being able to pump sewer water—Not if large or solid bodies are kept out of it.

78. What is the total quantity distributed in the metropolis daily?—About 50 million gallons daily; the minimum quantity may be 47 millions, and the maximum 60 on very dry days.

79. Is that a filtered supply?—There are but 3 of the London companies that give a filtered supply, viz., the Grand Junction, the Chelsea, and Southwark and Vauxhall.

80. At the rate you effect filtration it would not be worth while to convey filtered water for one kind of service and unfiltered for another?—No; another service of pipes would be a greater expense than the whole cost of filtering the entire quantity.

81. Of course, filtered water is less obnoxious to accidental causes?—I believe filtration to be indispensable to all waters; as a general rule, the more water is covered and kept from the air the better it is.

82. From your knowledge of other districts and the habits of the population, have you any reason to doubt that the same wants felt in your district are experienced in others?—I have not.

83. Have you anything to say with regard to the increasing pollution

of well-water?—Several wells in the metropolis have lately become so polluted as to have been disused; and in every situation where the population has been rapidly increasing, the well-water becomes thus affected. Mr. Quick.

84. If a system were adopted to prevent waste, do you see any grounds for supposing that the present water-supply would be in excess, after providing for street-cleansing, washing the fronts of houses, the use of baths, and other sanitary purposes?—I have no doubt that if proper means were adopted to prevent waste, a quantity of water, far more than sufficient, is at present supplied by the companies, for every purpose.

85. Has it been the practice of your Company to allow parties to join on to the trunk-main?—The trunk-mains are seldom tapped, except for the fire-service, but much use is made of the branch mains.

86. Even so far back as 20 years, were not persons allowed to have water direct from the main?—Yes, by making special arrangements as to price and quantity.

87. What additional quantities of water could the Grand Junction Company and the Vauxhall Water-works Company supply, with their present Works?—The present daily supply afforded by the Grand Junction Water Company during the past year has averaged, for seven days in the week, 3,544,716 gallons, and the engines which pump this quantity, by being worked their full time, would deliver 6,321,600 gallons. The Company have also, in addition, two powerful engines, capable of raising 6,566,400 gallons to an elevation of 150 feet, or 68 feet below the top of the stand-pipe. By a reduction of the pumps, they could be rendered capable of lifting 3,988,000 gallons to the height of the stand-pipe. The gross quantity the Company could then deliver at an elevation of 218 feet (minus the friction to be overcome in the flow of the water to London) would be 10,309,600 gallons, or three times the present supply. The present loss of head by friction would appear to be from 6 to 10 feet.

The Company have also two lifting-engines capable of raising 13,478,200 gallons of water from the Thames daily to their depositing reservoirs and filtering-beds, which reservoirs and beds are capable of nearly twice the work they at present perform. They have also land sufficient to increase their filtering reservoirs to any necessary extent.

The height of the stand-pipe being 218 feet, and the trunk main 30 inches in internal diameter, the above quantity of water could be pumped into the Company's district, in which the mains and services would be sufficient for its distribution.

The quantity of water supplied daily by the Southwark and Vauxhall Water Company during the past year, (seven days in the week,) has averaged 6,011,225 gallons. The same engines which pump this quantity, if worked to their full power and time, would deliver 8,000,000 gallons. The Company have also a spare engine, which, by reduction of the pump, could be made to lift 1,200,000 gallons daily, making a gross quantity of 9,200,000, or 50 per cent. above the present supply. The Company have provided room in their engine-house for an additional engine, capable of lifting 9,400,000 gallons to the top of the stand-pipes, and they would then have the power of giving a supply

Mr. Quick. three times greater than their present. The Company possess reservoirs of deposit and filtration quite equal to the gross quantity that could be pumped, and they have also spare land for additional filter-beds. They have, by a 4-feet culvert-pipe and a lifting-engine, the means of taking the whole of the water they at present use from the falling tide, after the London drainage has passed down the river, and any further quantity that might be required by the addition of another engine of the same description, the culvert being amply sufficient.

The height of the stand-pipes being 180 feet above Trinity high-water mark, their trunk mains of 20 and 27 inches diameter are quite equal to convey a double quantity of water, if required.

It will be understood that the quantities given above are the whole duty the engines would be capable of performing in actual working; allowance must be made for the time required for cleaning and occasional repairs, and also for the reserve necessary against the contingency of accident.

88. What proximately might be the expense if the supplies for the Grand Junction district, or the Southwark and Vauxhall district, were taken, say from near Thames Ditton?—With a view to afford a reply to this question, I have carefully examined the banks of the river between Thames Ditton and Kew Bridge, for the purpose of selecting a site for a pumping establishment that should be altogether beyond the influence of the London drainage, and where the water would be of the same quality as that passing at Thames Ditton.

The most suitable place for forming a work of this description I believe would be the Ait, or small island, opposite Twickenham, being situated within a mile and a quarter of Teddington Lock, and nearly five miles above Kew Bridge.

The accompanying plan will best show the position of the engine-house on the island, and the mains (coloured red) leading to the Grand Junction Works at Kew Bridge, and the Southwark and Vauxhall Works at Battersea Fields. Also the additional mains (coloured blue) that would be required to supply the West Middlesex and Chelsea districts from the Kew Works and Camden-hill reservoirs, and the Lambeth Company's district from the Battersea Works and the Brixton-hill reservoirs.

To effect these objects it would be necessary to enlarge the Kew Bridge Works, and make some additions to the Battersea Works.

The following estimates, numbered 1, 2, and 3, embrace the whole sums that would be required to form the pumping establishment at Twickenham: also to lay the mains to supply the two works of distribution at Kew Bridge and Battersea; the enlarging of the Kew Bridge Works and additions to the Battersea Works; and the laying of the mains for connecting the West Middlesex and Chelsea districts to the Kew Bridge Works, and the Lambeth district to the Battersea Works.

Estimate No. 1.—*Pumping Establishment at Twickenham.*

	£
Engines, &c.; engine-house, ground, &c.; culverts, &c., under the bed of the river to connect mains	50,000

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	£.
Brought forward	50,000
Estimate No. 2.—*Enlarging of the Kew Works.*	
(These estimates are made in reference to the present quantity supplied.) Additional engines, engine and boiler houses, land, filter-beds, and reservoirs, sundry connections, &c.	95,000
Additions to the Battersea Works.	
Additional engine, filter-bed, &c.	25,000
Estimate No. 3.—*Mains from Twickenham to the Works of Distribution at Kew and Battersea.*	
Twickenham to the Kew Works, 6600 yards of 36-inch main; ditto to Battersca Works, 17,600 yards 30-inch; Kew Works to the junction with the West Middlesex main, 4850 yards of 30-inch; from Camden Hill to the junction with the 24-inch main passing through Hyde-park, from the Uxbridge to the Knightsbridge roads, and to the Chelsea Company's mains, 3500 yards 30-inch main	121,550
From the Battersca Works to the Brixton-hill reservoirs, and connected to the Lambeth Company's mains, 4400 yards 24-inch main.	
	291,550
By land and old works	100,000
	£191,550

89. In the distribution of water do you find often the practical results correspond with the doctrines in hydraulics deduced from mathematical formulæ, or from experiments on a small scale?—As far as my experience has gone, I have never tested the difference between the theoretical and practical flow of water through pipes. In arranging new works of supply I would rather be guided by my own observations and what I know to be the general practice of the most experienced engineers, than by any mathematical formulæ, as, from all the recorded experiments on the subject, the theoretical and practical results seem to differ so materially.

90. Will you give practical illustrations of the discrepancies between the mathematical hydraulics and actual experience?—Not having made any experiments, I cannot.

91. What additional heads of water did the current hypothesis suggest, and what did practice prove to be sufficient for sending a double quantity of water through mains of the same diameter?—The current hypothesis would suggest a much greater altitude for producing an increased flow through the same pipes than I believe would be found necessary in practice.

92. It appears to be the common practice in laying down pipe water-supplies to lay down tapering mains, trunk mains, as well as branches.

Mr. Quick. Must not those systems lead to inequalities of pressure and deliveries?—The trunk and branch mains for supplying a district are generally arranged to convey as much water as possible to central situations, and are then gradually reduced in size as they approach its limits. This arrangement produces slight inequalities of pressure and deliveries, but the inconvenience is more than counterbalanced by the saving of capital.

93. Have any illustrations of this general fact come practically under your observation?—Only in this way, that, when great additions have been made to particular portions of the out districts of a water company, it has been found necessary either to increase the size of the pipes, or to lay a small independent main to assist them.

94. Will you describe them?—The pipes are made to bear a much greater pressure than they are ever subjected to, as it is necessary to provide against any sudden recoils that may take place in the opening and shutting of the mains, or from other causes.

95. It appears, then, that from your experience the chief limitations to the power of sending double or increased quantities of water through the existing mains would be the power of the mains themselves to bear the increased head of water?—I believe that to be the only limit.

96. Then you believe that you are sufficiently aware of the strength of iron mains to know closely the limits of safe pressure?—I do; but I beg to observe that the pressure of the water is not the only thing to be considered in estimating the strength of iron mains. Much depends on the regularity of thickness in the castings, and whether the ground in which they are laid is solid or liable to sink.

97. Does not the breakage of cast-iron pipes form one heavy item of the company's expenses?—The breakage of mains, when properly laid, is not a heavy item of expense; the principal outlay for street repairs is occasioned by the sinking of the ground, and the vibration caused by heavy loads passing over the pavements, shaking the joints of the small pipes, and loosening the ferrules of the house-service pipes.

98. To what may it have amounted per cent. on the pipes laid down?—The amount has been so indefinite that no separate account has been taken of it.

99. It appears that the Grand Junction Company's works comprise the largest cast-iron main (30 inches) laid down in the metropolis?—Yes, for any great length.

100. Have you any doubt that when properly protected by air-vessels they will act as pipes of an inferior description, as appears from the remains, were made to act by the Romans in the extensive distribution of water?—I believe that air-vessels placed at intervals (particularly on the summit-levels) would be a great protection to every description of main.

101. Are there any means of ascertaining what numbers of large wells are used within your district?—Only by special survey.

102. What trades or manufacturers usually use steam-engines or large machine power?—Brewers, distillers, millers, tanners, hatters, engineers, dyers, railways, saw-mills, gas-works, potters, printers, &c.

103. What manufacturers are there who use extra quantities of water?—Brewers, distillers, tanners, fellmongers, hair-washers, hatters, dyers, gas-works, potters, printers, chemists, &c.

Mr. Quick.

104. Will you look at the trades directory and see what numbers of them are indicated, and what proportion of them are situated within your district?—The Southwark Company supply upwards of 600 large and small manufacturers, and works that use extra quantities of water, many of whom have Artesian and deep wells on their premises, but prefer the river water for parts of their business; but it would require a special survey to ascertain the correct number.

105. Might not that main be broken for want of precaution?—There are several ways in which this may be done, either by opening or shutting a stop-cock suddenly, or, when under pressure, striking a sharp blow on the external surface.

106. It appears then that the greatest loss and the greatest danger to which the main and water pipes are exposed is from hydraulic jerks; now, on the constant system of supply, will not these be diminished?—The mains will be liable, in a certain degree, to the same hydraulic recoils in the two systems of supply, as it will be necessary to empty and charge them after repairs and alterations.

107. You are aware that earthenware pipes have been made which have only broken under pressures of upwards of 1500 feet, or more than 40 atmospheres?—I have been informed that such is the case.

108. What is the point of pressure at which you test cast-iron pipes? —The large trunk mains are usually proved by hydraulic pressure to a column of water 600 feet in altitude, and the smaller pipes to 300 and 400 feet.

109. Being more frangible, it may be expected that earthenware pipes will, notwithstanding their strength under steady pressure, be more exposed to hydraulic jerks?—I have no doubt this would be the case, from the difference in the cohesion of the particles of which the materials are composed; and perhaps cast iron would be assisted by the lead ring which forms the joint, and admits of a small amount of contraction or expansion.

110. Have you observed water in motion and conveying matter in suspension, and the same water interrupted in its flow so as to allow a partial settling?—I have; and found that a small current of water would keep a large quantity of heavy matter in motion; but if any interruption took place in the flow, and settling commenced, it required a considerable amount of labour, or an immense quantity of water, to set the deposit again in motion.

111. Have you observed what extra quantity of water it would take to move deposit after it has once become settled?—Much will depend on the nature of the deposit; if it is of a light, loose consistency, the same flow of water would remove it in a longer time; but if the débris from the roads is once allowed to become indurated in the drains, I do not think any amount of water, unless under immense pressure, would remove it.

112. Do you agree in the evidence of Mr. Lovick and Mr. Grant, as to the additional quantities of water that would be required to raise and remove deposit on an intermittent system of drainage, such as prevails on the Surrey side of the river, as contrasted with a constant flow produced by pumping or other means?—I perfectly agree with Mr. Lovick and Mr. Grant that great additional quantities of water would be required to remove the deposit consequent upon any intermittent

Mr. Quick. system of drainage, and I believe it would be found a greater economy, in situations like the Surrey side of the river, to receive the sewage in tanks or sumps, to be pumped into higher levels, than to pump the extra quantity of water that would be required for flushing after each deposit had taken place.

W. C. Mylne, Esq., examined.

Mr. Mylne. 1. You are, I believe, engineer to the New River Company?—I have been their engineer for about 40 years.

2. The Commissioners are desirous of knowing what is the quantity of water you have pumped in your district during the last 12 months?—The amount of water pumped in and supplied in the New River district during the last year (1849) has been estimated at about 2,109,339,311 gallons.

3. What was the quantity delivered per tenement?—The quantity delivered into London during the year 1849, when divided by the number of tenants, will average about 200 gallons each per day. I believe that is rather below the average given in the last return to Parliament. The sources from which the Company took their supply during the summer of 1849, were the Chadwell spring, which is calculated to give 500 cubic feet a minute; a supply branch from the river Lea, which is limited by an Act of Parliament to 1,340 cubic feet a minute; the well at Amwell End, from which we draw 150 cubic feet a minute; another at Amwell-hill, supplying the same quantity; a well at Cheshunt, yielding 60 cubic feet a minute; and another at Tottenham Court-road, giving 70 cubic feet a minute. These are the whole of our sources, excepting some small springs taken into the river in its course, and the water-shed of small districts collected at Cheshunt into reservoirs, and occasionally taken into the river. The town would have taken more than the above last summer if the Company could have distributed a larger supply. In June last, in consequence of the great dread from the presence of cholera, we found great difficulty in meeting the demands of the public for water, and I pointed out to the authorities at the Mansion House the circumstance that the Lord Mayor of London in 1832, when the cholera raged, applied to the trustees of the Lea for more water, and an unlimited quantity was then afforded. In consequence, a similar application was made to the trustees in 1849, and a limited quantity was granted, but at the end of a month it was withdrawn, which caused much dissatisfaction in the City.

4. Do you think that the Company would have any objection to allow the capacity of their works, and the average amount of flow of water therefrom, to be verified?—I should think the Company would have no objection whatever to the quantity being verified.

5. Have you had occasion to examine the actual consumption of water in houses of different classes?—I have. (See the annexed Table, p. 43, which shows the result of that examination.)

Comparison of the Consumption of Water in the Houses of the Poor and those of the better Classes, as also the customary Charges for the same.

Description of House.	Average Number of Inmates, per Room.	Average Consumption, per Day per Inmate, in Gallons.	Average Quantity consumed, per Day per Room.	Charge, per Room per Annum.	Price per Head per Annum, to which the Annual Charge is equivalent.	
				s.		
1st Class, having from 12 to 20 rooms, with proper cisternage	0·658	12·87	8·47	6·	9·11	High service charge, under 50 feet.
2nd Class, houses of the middle class ditto.	1·005	7·41	7·45	5·	4·97	High service, under 13 feet.
3rd Class, houses of the poor, having receptacles for water.	2·04	3·65	7·43	3·5	1·71	Low service only.
4th Class, courts and alleys, with common cocks, supplied once a-day.	2·86	5·11	14·63	3·	1·04	Low service only.

N.B.—The preceding averages are taken from 552 houses, containing 4,319 persons.

Consumption in the Dwellings of the Poor under Improved Management.

In the Model Lodging-houses and Workhouses.	Consumption, per Day per Head, in Gallons.	Number of Persons supplied.	Capacity of Cisternage per Head.	Charge, per Head per Annum.	Charge, per Family per Annum, taken at 5½ Persons.
George-street, St. Giles . . .	6·5	104	11·13	1·67	9·075
Model Buildings, St. Pancras-road	6·12	573	7·40	1·57	8·635
In Holborn Union Workhouse.	5·0	698	9·15	1·26	6·930
St. Martin's Workhouse. . .	3·68	601	6·31	1·26	6·930
Clerkenwell Workhouse . .	3·1	433	5·39	0·92	4·972

N.B.—The preceding averages are taken from supplies to 3,458 persons. In each case the cisternage (or quantity which may at any time be used) much exceeds the supposed ordinary consumption. If the model buildings in St. Pancras-road be taken as an example of what may generally be the number of inmates in improved dwellings for the poor, 1·84 will be the number of persons in each room, and 11·26 gallons the consumption per room per diem.

6. From your experience have you had the opportunity of observing that 4-inch tubular drains keep themselves clean without an extra supply of water, and that 6 or 9-inch branch sewers also keep themselves clean?—Yes, I am of that opinion, if they have a proper inclination.

7. Have you considered the advantage of the house-service pipes being carried at the back instead of the front of the houses?—To obtain a water supply to the house-service pipes from the backs instead of the fronts of the houses, the iron service-pipes should go through the back gardens of the houses.

8. Would it not save the expense of the length of service-pipes through the front premises from the centre of the street, to get them to the place where the water is used at the back, and thus save two-thirds of the length of service-pipes?—In wide streets, where there are iron service-pipes on each side, there would certainly be a saving by the depth of the house in the length of the leaden pipes used, and no greater extent of iron required. In narrow streets, where only one line of pipes is placed in the centre, there would be a greater length of leaden pipes saved, but the extent of iron pipe in use would be doubled.

Mr. Mylne.

9. What towns have you visited where there is a constant supply?—Ashton, Duckinfield, Leeds, Nottingham, Glasgow, Edinburgh.

10. Do you think that the Ashton works are, on the whole, a fair set of works?—Yes, they are very well managed.

11. Do you not consider a pail of water as containing about two gallons?—A pail of water contains in general about three gallons.

12. It is stated, that at Preston, where there is a constant supply, the actual consumption of water is about the same as you state in the metropolis, namely, about 55 gallons?—Having only passed through Preston in my way to other towns, without the opportunity of examining the works there, I have no means of answering this question.

13. What is your opinion with regard to the advantages of the constant system of water supply?—I think that where a domestic supply is required for a moral and well-conducted population, the constant system of supply is, under certain provisions, the most efficient, and in annual cost, I conceive, the cheapest. This opinion is given independent of sanitary requirements, with the extent of which we are at present but little acquainted. To work such an establishment well, it should be originally constructed for this system of supply, and the pipes should be laid deep in the ground to avoid the effects of frost. In expressing this opinion on the constant supply, I do not support the abandonment of the cisterns and tanks in respectable dwellings; one or more in every large house is essential for closet purposes, for steam apparatus, and to meet cases of unavoidable interruption of supply during repairs. A large tank in every cluster of houses occupied by the poor is also equally necessary, from which each house should be supplied. By these means the extreme pressure upon the taps in domestic use is reduced, and much wear and tear avoided. By thus retaining the use of tanks (either in slate or iron) there is the advantage of employing less capital in pipes, as they may then be employed in discharging the supplies for a more considerable portion of the 24 hours, and be able to extend without inconvenience to the consumer (what I have observed to be practised under the constant supply system) the wiredrawing the supplies to wasteful districts, and those of very low level, for the purpose of securing a more full discharge to other portions of the town at higher elevations. The more modern the town requiring to be supplied, the better adapted to this system of constant supply, for under such circumstances the large and respectable inhabited houses are found in one neighbourhood, and the labouring classes in another, and not intermixed, as in old towns. Among the very poor I disapprove much of the use of butts; the occupants too often dip with unclean vessels into them, and thus injure the quality of the water. As to stand-cocks in the public courts, they are well known to be particularly inconvenient, as well as a public nuisance. If the Water Companies were to erect large tanks (at a small additional charge), and take the control of them, from which each house should have a pipe, the constant means of obtaining water within the premises would be afforded in these miserable localities, which exist, in a greater or less degree, in every town in the kingdom.

In the application of the intermittent supply to long existing towns, where there is that intermixture of classes referred to above,

where all kinds of trades are on the increase and in full work, and manufacturers are removing their establishments from place to place, with districts crowded with inhabitants, without regular employment, and snatching a scanty subsistence by their wits, as occasion may afford, there exists many advantages in the intermittent over the constant system of supply. Upon this subject I have already expressed my opinion in a letter to Her Majesty's Commissioners of Sewers for the City of London, which I now subjoin. Mr. Mylne.

At a Meeting of the Commissioners of Sewers of the City of London, held, pursuant to adjournment, on Tuesday, the 27th day of March, 1849,

W. A. Peacock, Esq., Deputy, in the Chair.

The clerk lays before the Court the following letters, which are severally read:—

Dear Sir, *New River Head, March* 23, 1849.

In reply to your letter of the 3rd instant, requesting to be favoured with my opinion, for the information of the Commissioners of Sewers of the City of London, as to whether any really important difficulties exist to prevent a constant and general supply of water by the New River Company, and also what in my judgment would be likely to be the effect, in a sanitary point of view, of such a supply, I beg to state, that having made various experiments with a view to ascertain the practicability of carrying out such a system in London, I feel satisfied, from the existing internal arrangements of the distributary leaden pipes and cocks, which are all private property, from the great number of open pipes, from the neglect of not having ball-cocks thereon, and from the impossibility which would, under a constant supply, exist, of complying with the occasional demand of the public for temporary large supplies, it is quite impossible for the New River Company to afford a constant and general supply to the district where their pipes are laid, and fulfil their present engagements with the public.

As I have given the subject of constant supply much consideration, and as I have visited most of the large manufacturing towns where it has been introduced, I trust I may be excused for making some remarks on the difficulty attending such a system, in connexion with the existing engagements of the Company, and upon the very doubtful advantage its introduction would confer on the inhabitants of the metropolis of England, where so little restraint exists in the expenditure of capital upon the internal domestic arrangement for the consumption of water within their dwellings.

By the accompanying section of the town through the lines of the leading mains of the New River Company, it will be seen that the demand for water to tanks in the upper stories of the houses has become so general, that the original level of the reservoirs at the New River Head is quite inadequate for affording the high supply now required by the tenants.

It also gives some idea of the nature of the demand required in the various portions of the City and its suburbs.

Now the use of water from these tanks, as also from all the other cisterns, is intermittent; it is more particularly in demand during the earlier hours of each working day; the last day in the week demands the largest supply for domestic purposes, and during the heat of summer the demand very materially increases.

Supposing, therefore, that new reservoirs are to be obtained at a sufficient elevation, and within a reasonable distance, to ensure at all times a supply to these tanks, the increase in the dimensions of the pipes, to afford a constant and regular supply to all these tenants, would be so great that the most moderate

Mr. Mylne. interest upon the required outlay on pipes and reservoirs would far exceed the interest on the capital invested in cisterns for ordinary supplies.

By the present mode of supply, where so large a portion of the tenants are provided with proper tanks or cisterns for water, the public have ample means of obtaining a general supply, and by the application of the machinery of the Water Work establishments, the supply is distributed, under such a pressure as the circumstances at the time may require, directly into and through the iron pipes, and the public also obtain, under this system, for pressing circumstances, such as fires, &c., an advantage that would be wholly lost under the system of a constant supply.

Again, in the large manufacturing towns the houses are generally freeholds, or have been erected on ground feud out to individuals who cannot be disturbed; but in London nearly all is leasehold property, and where large traders are continually removing from one part of the town to another, their newly created positions are immediately satisfied through the medium of pressure, although the pipes may be quite inadequate to such a discharge under an ordinary and fixed head.

Again, very large and necessary intermittent supplies are required during the occasional failure of private machinery, in the supply from wells, as also from increased demand to extinguish fires, where extremely combustible materials may have been collected. and thus a far more extensive supply can be given at high elevations than could be afforded under the constant supply system.

I must further state, that means exist between the Water Companies of assisting each other, through communications made between their works, and that during the last season an application having been made to the New River Company for immediate assistance, an arrangement was entered into, and in a very short time the supply of 1,000 houses was commenced and has been continued for some time through pipes only capable of affording such an accommodation under the present system of supply.

Now, to continue all these advantages to the present tenants that are provided with proper pipes and cisterns for receiving an ample supply of water, and to secure the same to all the poorer inhabitants that may be residing in houses that are not provided with the necessary means for storing water, all that is required, and which I cannot too strongly recommend, is, that tanks should be enforced upon the landlords, and also in all the courts where common cocks exist or may hereafter be required.

These tanks might be made of wrought iron: thus the inhabitants of such courts would have the constant means of drawing water; and where the landlords cannot afford to erect them, the Water Companies should provide them on the receipt of a moderate interest from the landlords, the water-rent in all such cases being also paid by the landlords; and although I cannot professionally answer the latter part of your request as to the sanitary effect of a constant supply, I am decidedly of opinion that whatever advantages would arise to the poorer inhabitants from such supply in the opinion of medical officers, such would be equally obtained by what I have here recommended in respect to the enforcement of proper tanks or cisterns being provided by all landlords.

I remain, dear Sir,
Your's faithfully,
WILLIAM CHADWELL MYLNE, F.R.S.

Joseph Daw, Esq.,
Principal Clerk, &c.

SIR, *New River Office, March* 23, 1849.

IN forwarding, for the information of the Commissioners of Sewers of the City of London, Mr. Mylne's reply to your letter of the 3rd instant, I am desired by the Directors of the New River Company to furnish the following additional information touching the rate of charge, the quantity supplied, and the number of houses that do not receive water.

1st. Rate of Charge. Mr. Mylne.

On a careful examination of the water-rents paid within the City, it is found that the charge (as compared with the parochial returns of the rack-rent), does not exceed three per cent., and if the large consumers were excluded, the average rate for domestic supplies would be found considerably below this average.

2nd. Quantity supplied.

The average quantity of water supplied by the New River Company during the year 1848, gives for daily distribution (including the supplies afforded for sanitary purposes), a quantity per tenant equal to or more than 200 gallons. This quantity is capable of being increased in various ways, by farther outlay of capital, whenever it may be required; but even now such quantity is more than double the amount (as stated in evidence before the Health of Towns Commissioners) of the quantity delivered under the constant supply system, even at Nottingham, Preston, or Greenock, which have been represented as the standards of perfection.

3rd. Houses unsupplied.

In a prospectus lately put forth, it is stated that within the district supplied by the New River there are 300,000 persons unsupplied. As this appeared incredible, a strict inquiry has taken place, and the result turns out as follows, viz. :—

Old premises within the district, never supplied, and having wells or other modes of supply, or not requiring water	1,056
Houses taken off the works, not being inhabited, or not wishing to pay water-rent	986
	2,042
If five persons are taken as residing in each house, multiply by	5
Gives the number of persons unsupplied by the New River water	10,210

I also enclose, by direction of the Board, a copy of the section referred to in Mr. Mylne's letter, for the use of the Commissioners.

I have the honour to be, Sir,

Your most obedient servant,

Joseph Daw, *Esq.*, FRED. INGLIS, *Clerk.*
&c. &c.

Ordered,—That the same be printed, and a copy be sent to every member of the Court.

JOSEPH DAW, *Principal Clerk.*

Captain Vetch examined.

1. Have you not given great attention to measures of sanitary improvement; and have you not been consulted from time to time with respect to the drainage of towns?—Yes. Capt. Vetch.

2. And with respect to the drainage of Windsor?—Yes.

3. Have you not taken a view of the present supply of water from the Thames?—Yes.

Capt. Vetch. 4. Will you state to the Commissioners your views as to the objections to the mode of conducting the water from its sources, near Ware, by the New River, to London?—The New River derives its chief supply of water from the river Lea, a little above the town of Ware, the amount however being limited to 1·340 cube feet per minute; from the Shadwell springs, and other sources near the same locality it has a further supply of 860 cube feet per minute, (part of which is pumped,) thus obtaining from near Ware, a total supply of 2,200 cube feet per minute, or 3,168,000 per diem. When the New River was projected we learn that the springs at Chadwell and Amwell comprised all the water intended to be taken to London at that time (1606), and probably the supply of water by these springs was then equal to the requirement. The mode of conduction adopted for the water was that of an open canal or mill-leat, constructed nearly on a level, having an inclination of only 3 inches per mile, and to avoid tunnels, and cuttings, embankments, and arcades, the leat was made to follow all the sinuosities of the ground (as on a contour line,) and similar to the mode resorted to of the rudest kind, and for the rudest purpose, but in keeping with the age and its wants, and when the work was accomplished in 1613, it no doubt conferred a great boon on the inhabitants of London, and does so still from want of a comprehensive work of art and science worthy of the present day, and equal to the requirements of the present population. Within the present century, great ingenuity and great expense have been applied by the New River Company to correct the evils of the rude and vicious mode of conduit first adopted, and little more improvement can be effected in that direction, indeed such praiseworthy zeal would be better applied to change the system entirely, but probably the very great misapplication of funds and talents to perfect in detail what was defective in principle, may have served to protract the existing works in their primitive form to the exclusion of others more capable of meeting the demands of the day. The New River or canal is about 18 feet wide and 4 feet deep, and extends from the site of the ballance-engine, at the river Lea, near Ware, to the New River Head, at Clerkenwell, over a tortuous length of about 39 miles, while the distance by a straight line is only about half as much; the water is received from the Lea on a level of about 100 feet above high-water mark in the Thames, and is delivered at Clerkenwell at 84 feet above the same, or with a total descent of 16 feet, for though the inclination of the surface of the water is graduated to a descent of 3 inches per mile, or 10 feet in the whole distance, there are some overfalls which add 6 feet more to the descent. A great objection to the conveyance of water for domestic purposes in an open earthern channel is, that the water must have a very slow motion, not exceeding half a-mile per hour, to prevent the current wearing the channel-bed, and bringing in turbid water; the slow motion is again attended with serious evils, depositions of silt and decayed vegetable matter take place, which require to be cleaned out from time to time; in the warm season, so long and broad a surface exposed to the atmosphere, gets heated to a degree favourable to the production of vegetable and animal life of the lower forms, and also in giving rise to a considerable quantity of waste from evaporation, the high temperature

of the water further facilitates the decoction of leaves and other vegetable matters, which get blown into the New River, to the manifest injury of the water, but there are other pollutions of a worse character, to which all open canals are subject. It is true the New River Company have five acres of settling pools at Clerkenwell and 38 at Newington, for the deposit of solid matters, but exposed as such broad surfaces must be to the summer heats, it may be doubted if the tendency thus afforded to the germination of animal and vegetable life and decoction of vegetable matters, do not create more evil than good. Such are the objections to all open water conduits conducted in earthern channels, the deficiencies of which will however be still better appreciated by a contrast with the qualifications that may be obtained for the same water if conveyed in covered channels constructed of stone or brick-work, and conducted in straight lines with an uniform and efficient descent, crossing valleys on embankments or arcades, and piercing hills by tunnels or adits; for example, the water of the river Lea might be conducted to London in such a channel, from Ware, at a distance of 20 miles instead of 40, and with a speed of one mile per hour instead of half a mile, that is, the transit would be accomplished in 20 hours instead of 80; and during its course it would receive no heat from the atmosphere, but, coming most of the distance in a tunnel the water would arrive as cool as when delivered from the spring; it could receive pollutions of no kind in its course, nor would it be subject to waste from evaporation; being exposed neither to light nor heat, no tendency would be created to germinate animal or vegetable life, to which also the increased velocity of current would serve as a preventative, and the water remaining pure, no settling tanks would be required but simply distributing basins; much greater things may however be done, for supplying London with pure water, than the mere contrast now noted. Though Sir Hugh Middleton and his successors did not hit upon the most unobjectionable mode of bringing water to London, they were certainly very near the best sources of supply; at Hertford there is a singular meeting of four copious streams of water, proceeding from chalk valleys, viz., *the Lea*, *the Mimram*, *the Beane*, and *the Rib*, which jointly have a discharge of between 6,000 and 7,000 cube feet per minute, or 9,360,000 cube feet per diem; the above streams are mainly derived from springs, one of these at Woolmers, the seat of Mr. Woodhouse, yields about 300,000 cube feet per diem, rising from or through the chalk beds, and which are perennial, clear, copious, and cool, and from some investigations instituted by the Commissioners of Sewers, it appears to me that, by means of a covered brick conduit running in a straight line from near Trinity Church, Holloway-road, to a farm-stead on the river Lea, called Watery Hall, two and a-half miles above Hertford, the several streams above-mentioned may be collected together at the latter named place, and the greater part of the water brought to a distributing reservoir at the Holloway-road, upon a distance of not more than 14 miles, and with a gradient of about 5 inches per mile, at the rate of one mile per hour, that is a quantity three times the amount of that now brought in by the New River Company, and sufficient for the supply of the whole of London north of the Thames; further, the water would be delivered without any pumping, at an Capt. Vetch.

Capt. Vetch. elevation of 140 feet above high-water mark, whereas the New River Company only deliver its water at Clerkenwell, at an elevation of 84 feet, and wherefore high service is obliged to be pumped up 60 feet.

In speaking of the New River waterworks, I wish to be allowed to add, that notwithstanding the objections which I have taken to the long, open, and tortuous channel for conducting the supply, I consider the New River Company to be the best establishment for its object in the metropolis. The sources of its supply are good; the principle of conducting the water by gravitation is good, but the manner is bad; the water delivered by the Company I conceive to be the best supplied to London, and the charges for the same the most moderate.

In addition to the streams above mentioned, as applicable to the supply of water to London, there remains to be noticed the streams of the Ash, the Stort, and springs which join the river Lea below Ware, the joint discharge of which may be estimated at 3,000 cube feet per minute, or about 4,320,000 cubic feet of water per day. Such are the resources of the river Lea and its tributaries, and which for the paramount object of supplying the increasing population of the metropolis with so needful an element of health and consumption ought to be held sacred for that purpose alone.

I beg to hand in a letter and table which I have just received from my friend, Mr. N. Beardmore, who has been investigating, with Mr. Rendel, the discharges of the streams and springs constituting the River Lea, and to whom I am much indebted for data afforded to me. From the table it will be seen that the daily yield of the conjoint waters at Field's Weir amounts to fourteen and a half millions of cubic feet, or ninety-four and a quarter millions of gallons per diem. The water was guaged by Mr. James Hunter, of Bow, as well as by Mr. Beardmore:—

RIVER LEA.

13, *Great College-street, Westminster,*
25th March, 1850.

Dear Sir,

I now beg to transmit an estimate of the discharge of the river at various points visited by you on the 10th instant. We had rather too much surplus at Ware, but it appeared we had not allowed for waste at the sluices above, which did not escape your observation.

The estimate of the run per square-mile is a method which I adopt for comparing rivers; and it is added for your use if you feel it applicable. To make this consistent, the New River and Chadwell spring are added to the observed volume at Ware, and at Fielde's Weir (the junction of the Stort), you will observe the low run of the Stort and the Ash per square mile, the enormous run of the Mimram (remarkably steady at all seasons), and the great increase of the river between the town of Ware and the Stort junction; this latter we cannot account for by any patent facts, the whole district is full of springs, and must be gaining water in all directions, for the increase is systematic in all our guagings.

I am,
Yours faithfully,
Nathaniel Beardmore.

To Captain Vetch, R.E.

Capt. Vetch.

STATEMENT of the Discharge of the River Lea between Hertford and Field's Weir, March, 1850.

—	Cubic Feet per Minute.	Total Cubic Feet per Minute.	Square Miles of Drainage.	Run per Square Mile in Cubic Feet per Minute.
Discharge of Branches above Hertford.				
Lea proper at Horns Mill	2,096	..	112	18·71
River Beane at Molewood	1,483	..	83	12·42
River Rib at Ware Park	959	..	61	14·34
River Mimram at Panshanger	1,532	..	29·3	52·39
Brooks not gauged	89	..	4·7	18·63
Total above Hertford		6,159		21·23
Main river at Ware Mill	5,344	..	..	..
New River	1,250	6,594	..	..
Chadwell spring, say	506	..	..	..
Total valley at Ware	..	7,100	292·5	24·27
Area to Hertford . 290 sq. miles				
Add to Ware . . 2·5 ,,				
Total . . 292·5 sq. miles				
Field's Weir. (81 feet above Trinity high-water mark.)				
Stort proportion	1,376	..	105	13·10
Ash proportion	480	..	44	10·90
Run at Ware, as above	5,344	..	..	..
Increase from spriugs between Ware and Fielde's Weir	1,100	..	..	..
Total without the New River	..	8,300	..	..
Add for New River, &c.	..	1,750	..	..
Total of joint valleys	..	10,050	444	22·63

Note.—Fielde's weir is 81 feet above Trinity high-water mark. In the month of March, 1850 (a particularly dry one), the mean discharge of water over it was 8,000 cube feet per minute, exclusive of the abstractions by the New River; and the lock-keeper at the weir is of opinion that the discharge of March, 1850, is about what occurs in the dry months of summer.

5. Have you had any opportunities of eye surveys or any other surveys of the water-sources on the south side of the Thames?—Yes; I have especially directed my attention to the waters of the river Darenth, which discharges into the Thames, near Dartford, as I deemed it highly important in the first place, to investigate the cases of supplies from rivers discharging into the Thames, below London, the effect of which can be of little use in purging the Thames of the impurities collected in its passage through the metropolis, and which may therefore be abstracted without detriment. From the investigation made by the sanction of the Commissioners of Sewers, I find the yield of the river Darenth, near Shoreham, where its bed is elevated 148 feet above high-water mark, to be about 2,600,000 cube feet per diem, and

Capt. Vetch. which might be delivered through a brick conduit $12\frac{1}{2}$ miles long, to a distributory reservoir at Forest Hill or Manor Rise at a height of 142 feet above high-water mark. The river Darenth, like the Lee on the north side of London, is pretty constant in quantity, being chiefly fed by springs proceeding from the lower beds of chalk, or from the green sand below it; these springs are particularly numerous near Otford, but, were the conduit I have mentioned constructed, it would intercept other sources of supply, amongst others, a spring at Orpington yielding 223,000 cube feet per diem, and I estimate its efficiency would be equal to about 3,000,000 cubic feet daily for the supply of London south of the Thames. The conduits I have proposed on either side of the Thames, would be chiefly tunnels, or in miners' phrase, *adits*, in their character, and need not terminate at 13 or 14 miles, but may be gradually extended with a rise of about 6 inches per mile, which is ample, and if so continued they would, at no great distance, penetrate the green sands and wealden sands below the chalk, and so open subterranean lakes of pure filtered water for the supply of London, cool in summer and temperate in winter, a great advantage which subterranean reservoirs have over all other modes of supply. (*Handed in a map of the country, showing the sources and proposed conduits, for supplying London with water.*)

6. What do you pay for your own supply of water; and how are you satisfied with the same?—I am charged 9*l.* 12*s.* 6*d.* per annum. The supply is let on three times a-week, through a pipe about one inch in diameter; the cisterns are not capable of holding a greater supply than 473 gallons, and I find I have a quantity equal to about 14 gallons per head daily. How much the Company would supply if the cisterns were larger, I cannot tell. I am, however, sometimes disappointed in the water coming in at the appointed time; care has therefore to be taken that the cisterns are never exhausted, a precaution which limits the use of water. If the supply does not come on at the usual time, considerable trouble is occasioned in sending to the turncock, who lives at a distance; and the answer is, the water will be let on next day, or that the ball-cock or something must be out of order in the house; and as these ball-cocks seem to be made on principle to get out of order, it is difficult to tell whether the Water Company or the plumber is to blame, but between the two much inconvenience is occasioned. At times there is a considerable deposit of silt in the cisterns, and in warm weather small insects often abound, so that the cisterns require to be frequently cleaned out. All of which evils I conceive might be obviated by the system of constant supply at high-pressure; an alteration which might also save the Water Company from some abuse, that more properly belongs to builders and plumbers.

7. Have you had occasion to complain of injustice at the hands of any Water Company?—Yes. At a former residence I found out I was charged 23 per cent. higher than my next neighbour, whose house was precisely similar to my own, and a little higher rented. I complained to the Company, but after several months correspondence, could obtain no remedy. I was told by the collector at last, that they would raise the rate upon my neighbour if I insisted upon an equality; an offer which I declined.

8. What is your opinion of the usual charge for high-service?—I find it the practice of several Water Companies to charge high-service

whenever there is a cistern six feet above the ground-floor, which appears to me an ingenious device for charging high-service to every respectable house, however small, because if there be a water-closet anywhere but in the basement-floor, it must have a cistern six feet above the ground-floor; and Mr. Hawkesly, a good authority in such matters, states that, raising water 50 feet additional, costs but 5 or 6 per cent. outlay on the low-service, and consequently raising the water but 10 feet higher, ought only to cost the Companies about 1 per cent. on the low-service; whereas they actually charge about 25 per cent. on the same. Capt. Vetch.

9. Do you recommend any other aqueducts for conveying water to London?—Yes; considering that the population af the Metropolis has nearly doubled itself in 45 years, that is from 1800 to 1845, and that great solicitude is entertained that the same ratio of increase may continue to 1890, I consider it a most important measure to secure all the best supplies of water that can be obtained near London, before they be appropriated to other objects of minor importance; and while there still exist many facilities for carrying out the necessary works which the increase of buildings in and round the Metropolis may by-and-by render almost impracticable at any cost.

10. What other are the sources which you consider ought now to be secured for the benefit of the metropolis?—I conceive, in the first place, that the water of the River Verulam is the first to be secured, and rendered available for the public good of London; the water of this river, taken a little way above Watford, is a never-failing stream, derived from springs, and yielding 3 millions cubic feet of water per diem, at an altitude of 158 feet above high water in the Thames. This beautiful supply of water may be brought to a reservoir near the Blind School, Finchley-road, within three miles of Regent-street, by an aqueduct carried in a straight line for a distance of 12 miles only, and with a descent of five or six feet, it would be delivered at the reservoir at 152 feet of altitude above the Thames, in a space of 12 hours' journey from the river. The proposed aqueduct should be cased in brickwork, and carried chiefly under ground, secure from heat and all sources of pollution. It seems the more necessary to secure this source of supply for the public benefit, as its good qualities are too well known to allow it to remain long unfingered by some commercial Water Company. Indeed there is a Bill before Parliament this year, which proposes to appropriate the same, and to drive it up by steam-power to high reservoirs at Stanmore, Elmstree, Harrow, and Hampstead, for the supply of the outskirts and country villages; whereas it may flow, by gravitation, in a fine stream, high enough for the wants of the great Metropolis, and appropriated to any other purpose would be an act of profanation.

Similar to the supplies of water on the north-east of London, which unite to constitute the River Lea, those on the north-west of London unite to constitute the River Colne, and consist of the following streams. The Colne proper, an insignificant brook in dry weather, but subject to certain floods, deriving its supply chiefly from a surface of London clay, extending from Chipping Barnet to North Myms. In dry weather the stream seems to be deposited in swallow holes of the chalk, but in wet weather the water collects in a pool, and overflows the lip of its basin, and thence joins the Verulam.

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The Verulam, a fine stream, having a course of 19 miles through a chalk valley, is chiefly fed from springs, and is clear and constant, with an average yield of about three millions cube feet per diem.

The Gade, a fine stream, with a course of 14 miles through a chalk valley, is chiefly fed by springs, and yields a supply of about four millions cube feet per diem.

The Chess, a fine stream, flows for nine miles through a chalk valley, is fed by springs, is constant and clear, and yields somewhat better than two millions cube feet per diem.

The above streams have their waters united a little way above Rickmansworth, where their joint yield or discharge amounts to seven and three-quarters millions cube feet per diem, a great increase on the quantity afforded by them separately, but presenting a fact similar to what is observed on the River Lea at Field's Weir, the united streams in both cases showing a great accession of water from springs presumed to exist in the beds of the rivers, and which may be explained by supposing that the Lea and the Colne, throughout a great extent of their course, flow on the line of a great rent of the chalk formation, which probably extends from Widford, on the north-east, to Maplecross, on the south-west, a distance of 28 miles, and which line crosses the swallow-holes in the chalk at North Myms above alluded to.

It would be practicable, if so required, to unite the waters of the Verulam, Gade, and Chess, at a place near Moor House, about one mile east of Rickmansworth, and to convey their joint yield by a straight and covered aqueduct to the site for a reservoir already suggested near the Blind-school, New Finchley-road, and deliver the same at an altitude of 142 feet above Trinity high-water mark, and by a channel of about thirteen miles in length.

11. Will you notice any remaining sources you would suggest for the supply of water to London?—The fourth and last aqueduct which might be proposed to be applied to bring water to the Metropolis, would receive the waters of the River Mole at a point one mile east from Betchworth, above which point the river forks out into six great branches, besides smaller ones, unwatering altogether a district of strata underlying the chalk, equal in extent to about 100 square miles; and I am of opinion that the water obtained at this point would not seriously abstract from the quantity of water conveyed by the Mole into the Thames; as below the point at which it is proposed to be intercepted, the waters get seriously diminished in passing through an absorbent soil, which drinks up the supply to no beneficial purpose. The aqueduct to bring home the supply of the Mole to a reservoir on the high ground near Streatham, would be 15 miles in length, and chiefly carried under ground by a tunnel or adit, which would, as in the other cases, bring home the water cool and free from any possible means of pollution in its transit; and I estimate that three million cubic feet may be brought in as a daily supply. This last source of supply is of a very different nature from those which I have already named, and requires more investigation than I have yet been able to bestow upon it; I have therefore only to notice it as a probable source at a short distance from the metropolis, which may be advantageously made available.

12. What provision do you propose for the aëration of the water brought in by these brick conduits?—The size of the culverts will be

such as to permit a column of air, nearly equal to that of the water, passing along with it; the flow of the water would be regulated nearly at the rate of one mile per hour. Besides, at intervals there would be ventilating shafts reaching to the surface, and receptacles at various intervals for the deposit of any sedimentary or solid matter. Capt. Vetch.

13. Do you propose to aid the supplies of water by means of artesian wells or *bore-holes*, or by pumping up the natural subterranean resources?—No, I should particularly avoid resorting to any such means of forcing the subterranean reservoirs; and conceive that all such expedients ought to be interdicted, as interfering with the constant resources freely offered through natural means.

14. Do you apprehend much difficulty and opposition on the part of landowners and millowners to the construction of the aqueducts you advocate?—The interference with land by the kind of aqueduct proposed would be the least possible, since very little surface ground would be required—the conduits taking generally an under-ground course, so that little more than a right-of-way would become necessary; and there would be little or no interference with the rights and usages of the surface of the land. No doubt full compensation must be made for the loss of water to those now enjoying the use of it. Were the supplies of water and right-of-way sought to be obtained for the purposes of a private company as a commercial speculation, I conceive extravagant demands would be made upon such company, and every difficulty placed in its way, and with some reason, as no one is disposed to have his rights and property taken from him on compulsion, to serve the purposes of a private speculation; but much otherwise, I conceive, would be the feelings of the same persons if they understood what they were required to part with was for the benefit of a great public measure, from which the promoters were to derive no personal benefit; feelings which I have often heard expressed on this and similar occasions. I am, therefore, inclined to believe that the owners of properties under the circumstances proposed, would be content with what would be deemed a just and proper value for their rights and properties; and this view of the subject leads me to an opinion that, it would be impossible to carry any great and comprehensive measure at any reasonable cost, for the supply of the Metropolis with water, except as a measure undertaken for and by the public.

15. Will you state what will be the length of the several aqueducts you propose, and what the quantity of water you propose to bring into London by each?—The Lea aqueduct, 14 miles long, to bring in a supply of 7,000,000 of cubic feet per diem, and deliver the same at an elevation of 140 feet above Trinity high-water mark.

Secondly. The Darenth aqueduct, 13 miles long, to bring in a supply of 3,000,000 of cubic feet per diem.

Thirdly. The Colne aqueduct, 12 miles long, to bring in 3,000,000 per diem.

Fourthly. The Mole aqueduct, 15 miles long, to bring in, from a point on the course of that river, a little way above the village of Betchworth, about 3,000,000 of cubic feet per diem.

The drainage area of the Mole above the point of interception is somewhat more than 100 square miles, and it is probable that much good

Capt. Vetch. gathering ground exists in the district, which would much increase the amount of supply.

Aqueduct.	Length in Statute Miles.	Supply of Water per diem in Cube Feet.
Lea	14	7,000,000
Darenth. . .	13	3,000,000
Colne . . .	12	3,000,000
Mole . . .	15	3,000,000
Total. .	54	16,000,000

The above supplies may all be delivered to reservoirs 140 feet above high-water mark; and while the quantity of water proposed to be taken from the present discharge of the Lea and the Colne might (if thought fit) be greatly increased, it is reasonable to believe that the prosecution of the driftways would cut open many springs, so as materially to add to the supply.

16. Do you not consider the above quantity of water as unnecessarily great?—If water can be brought to London from such short distances, and at such an altitude, on the gravitating system alone—cool, and clear in quality, I do not consider that any quantity of such water, and under such conditions, can be deemed over abundant for the health of the population; and which, at the present ratio of increase, may amount, in forty years, to about 4,000,000 of souls. The supply of water to the population of Rome at present is estimated at the rate of 5 cubic feet per person per day; but under the *Empire* we learn that the quantity actually supplied by the Roman aqueducts amounted to about 50,000,000 cubic feet per day, for the use of a population presumed to have con-consisted of about 1,000,000. Amongst the numerous grand works constructed by the Romans, for the supply of water to the capital, may be mentioned the aqueduct of *Aqua Claudiæ*, which is stated to have passed through a subterranean channel 36¼ miles in length; while that of the *Aqua Martia* is said to have entered a tunnel 16 feet in diameter, in which it was conveyed for a distance of 38 miles. These and other great works constructed by the Romans for the supply of so important an element of life and health to crowded populations, ought to serve as a stimulus to pursue the same bold tract in supplying water to the greatest city known in history—the metropolis of the British empire.

17. What is the quality of the water which the sources you have mentioned will supply?—The waters, when derived near their sources, will be remarkably free from all animal and vegetable substances; but coming chiefly from springs in seams of the chalk formation, or passing through them, I expect they would be found nearly similar to the water in the New River near Ware—that is, of 16 degrees of Clark's test for hardness; and containing about 20½ grains of earthen salts in chemical solution, chiefly *bicarbonate* of lime — conditions, no doubt, unfavourable for washing purposes, but it must be allowed that a certain amount of bicarbonate of lime is useful in preserving the water from corrupting influences, and that it renders the water more grateful to the taste; and that of the two evils (as far as sanitary objects are concerned) it is better

to have *bicarbonate of lime* than animal and vegetable matter, causing putrescence in the water. For instance, looking at Mr. Brand's analysis of water at page 102 of Sir William Clay's recent pamphlet, it will be seen that the water in the Paddington Canal at Kensal Green, (where it is supplied to some extent from the *Ruislip* reservoir, gathered from the surface,) has only a hardness of 8¾° according to Clark's test, and contains only 11½ grains of solid matter per gallon, and in these two particulars twice as pure as the water of the New River; but such water is nevertheless very filthy, from animal and vegetable contamination; and I may mention here that about fourteen months ago the following description (from good authority) of the condition of the water of a canal near London, came under my notice:—" Even when the water is clear, it is very deleterious, producing, if used for drinking, diarrhœa and large pustules on the body; but at times the water is so much discoloured from vegetable matter, that it has the appearance of tan-pit water; and the barges passing along the canal are so deeply laden, that they stir up the clay from the bottom and sides of the canal, and leave the water in a muddy state." Capt. Vetch.

18. Has your attention been called to the scheme for bringing water from the Thames at Henley, for the supply of London?—It has, particularly to the scheme of last year, which appeared to be designed for the double purpose of a navigation and a supply of water to London for domestic purposes. The scheme of this year appears more distinctly devoted to the purpose of an aqueduct, but is not very comprehensible in its arrangement, if that be its only object. Last year the scheme was avowedly one to connect the navigation of the Grand Junction Canal with that of the Thames at Henley, and was described by the promoters in February, 1849, in the following terms:— "The water will be obtained from the Henley Reach of the river Thames, and carried by an aqueduct or *waterway* 18 miles long, to the Grand Junction Canal near West Drayton, and thence in the canal (which will be deepened for the purpose), to London. This channel will be lined throughout from Henley to London, and will conduct the water by a scarcely perceptible fall of 42 inches in the whole distance—about 33 miles." Elsewhere the promoters state—" The channel between Henley and West Drayton will be navigable, and will have the effect of diminishing the navigable distance between Henley and London, by more than 20 miles. A uniform surface will be preserved throughout the whole distance; and to maintain the purity of the water, the bed of the whole channel would be formed of concrete." And elsewhere, speaking of the contamination of the water by canal purposes, the promoters state—" That objection will be removed by the reflection that 100 barges a-day can produce no effect on the vast body of water in question."

Last session it was proposed that the water so brought to London should flow from the reservoirs direct into the mains, for the supply of the lower portion of the metropolis; and that the descent of such water should be applied to hydraulic machines to force up another portion of the supply required by the higher districts of the metropolis; and the Water Companies were to be invited to become the purchasers, and to convey the water brought from Henley through their own pipes. In the Bill before Parliament it was, however, provided, that when any house was situated within 100 yards of any main of the proposed Company, the

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owner might require to be supplied from it at a fixed rate. It ought, however, to be mentioned that the prospectus stated that if the combination of navigation with a supply of water for domestic purposes should be considered undesirable by Parliament, the promoters will increase their capital by 250,000*l.*, and make a channel separate from, though parallel with and adjacent to the Grand Junction Canal; but it was not explained that the combination of the two purposes on the distance between West Drayton and Henley would be relinquished; there can be little doubt, that as a canal project, the scheme of last year was quite suitable; and if the Grand Junction Canal had been connected at West Drayton with the Thames at Henley, the object of the promoters would probably have been achieved; the proposed fall of about 1 inch per mile would have produced a flow of about half a mile per hour, quite compatible with navigation purposes, and for bringing in a supply of water for the use of the eastern portion of the canal. If the undertakers abstained from laying down mains in the streets, no calls could be made upon them for supplies for domestic purposes; and if the water Companies refrained from purchasing the waters of the undertakers, the scheme would have become solely and entirely one of navigation; indeed the mere proposal to bring the water through the Paddington Canal would have been sufficient to put that part of the question at rest.

The Henley scheme of this year is too parallel, in many of its features, with that of last session to be freed from misgivings of some connexion with canals. For instance, the proposed cut from Henley to West Drayton is to be 19½ miles long, 40 feet wide, and 10 feet deep, with a very gentle descent of 1 inch, or less, per mile; it is stated to be capable of bringing 200,000,000 gallons of water from Henley to West Drayton, daily. The continuation of the aqueduct is then to run a distance of 11 miles parallel and adjacent to the canal, in a channel only 20 feet wide and 7 feet deep. This channel is proposed to convey 100,000,000 gallons per day from the larger channel to London, for domestic purposes, while the other 100,000,000 gallons, of which the Thames is to be robbed, is to be conveyed through the canal to London, for the ostensible purpose of flushing the sewers therewith; but how it is to be distributed for that purpose, and at what cost, is not shown. But though 200,000,000 gallons of water may thus be abstracted from the Thames daily, I do not find that the smaller channel, as far as the data will allow me to judge, could convey more than 60,000,000 gallons daily. If, for sake of argument, it be admitted that the object of the promoters of this scheme is exclusively that of supplying London with water for domestic purposes, then all the objections that I have stated to the conduit of the New River will equally apply to the open channel proposed for this scheme; the motion of the water would be very slow, and in summer would promote all the tendencies to animal and vegetable corruptions, to which it would be more exposed by reason of its extensive proximity to a canal. So much for the gravitation portion of the question; but when the water is brought to Paddington, it is then proposed to pump a certain portion of it to an elevation of 268 feet to a reservoir at Hampstead. If so much pumping is required, it may be asked whether the water would not be much purer, and cheaper conveyed, if pumped direct from the Thames somewhere near Twickenham, to reservoirs at London. The great objection, however, which I take to this scheme

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consists in the very large quantity of water it is to abstract from the Thames—about one-third of the whole quantity running over the Teddington Weir in summer, whereas the whole quantity now delivered there is not sufficient to maintain the river pure in its passage through London. The promoters of the Henley scheme of this year conclude their statement by proposing that the management of the undertaking be vested in a Board, to be selected by the ratepayers of the metropolis; but in that case it may be fairly asked why the same Board should not be allowed to select for themselves the sources of supply, and the mode of conducting the water of London.

19. If water be taken from the Thames, do you conceive it would be better to receive it at a considerable distance up the stream, as at Henley or Mapledurham; or only a short way, above Teddington Weir?—I conceive, in summer weather, if one-third of the water be abstracted from the Thames at Henley, the remainder would not reach Teddington equal in quality and quantity as before the abstraction; the volume and depth of the remaining two-thirds being so much diminished and the bed of the channel remaining the same, the velocity of the stream would be much reduced, and, from the slow motion and reduced volume, the water would get warm and evaporated to a much greater degree; the germination of animal and vegetable life would be promoted, which would corrupt and further diminish the volume of water, so that in a very dry season it is probable that only one-half the remainder would reach Teddington Weir, and in anything but a wholesome state; indeed, if such circumstances were to occur in a warmer climate than our own, an abstraction of one-half of a river, so far from the tides, would often prevent the other half reaching so far; I, therefore, consider it very important to preserve the stream of the Thames entire, cool, and clean, that its water should be permitted to flow in one united stream till at or near to the tidal compartment of the river.

20. If the water were permitted to be taken from the Thames above the influence of the tides, where do you conceive it would be most expedient to take it from?—As near above Teddington Weir as local circumstances would permit; and as the supply of water to the Thames must, to a considerable extent, be pumped, whether abstracted at Mapledurham or Twickenham, it would be an important point to reduce the expenditure of steam-power, in lifting the water, as low as possible, and for that purpose getting rid, to the greatest extent, of friction to the pipes conveying the waters to the reservoirs for distribution; and, looking at the problem as a miner, I have little hesitation in prefering the principle of action propounded by Mr. Philip Taylor in 1824, who proposed to supply London with pure water from the Thames at a point to be selected near Twickenham, and conveying it thence in a brick culvert or tunnel for nine miles, until it reached the site of appropriate reservoirs near Hampstead, up to which it would be pumped perpendicularly through shafts provided for that purpose, by powerful engines on the Cornish principle; and he justly stated, that the forcing water through a great length of iron pipes up inclined planes, was attended with so much friction, that one-fourth of the expense would be saved by a direct perpendicular rift; but how much of the saving would be due to the superior kind of engine, and how much to the diminished friction, did not exactly appear. There can be no doubt, on Mr. Taylor's plan, the steam power could be used with the best effect,

Capt. Vetch. and with no other friction from pipes than those constituting pumps: approving of Mr. Taylor's principle, probably the details might be improved upon, though I sincerely trust, that be its merits what they may, they will not form a sufficient inducement to use the water from the Thames for supplying the metropolis, until other and better sources have been found insufficient.

21. What objections have you to taking water from the River Thames above the tidal range for the supply of London?—There appears to me many important objections to abstracting the Thames water if to be obtained in a sufficient quantity from other sources. First, I conceive the purity of the water of the Thames between Battersea-bridge and Blackwall to be essential to the sanitary condition of the population located on its banks; that for many years I conceive it has been becoming more impure; and that its safety from a worse fate is chiefly due to the amount of fresh water delivered daily over Teddington Weir into the tidal compartment of the river; that the increasing impurity of the river, in the section alluded to, is manifest to many who have had occasion to observe it; nor can the fact be denied, since, through the constant increase of population, the refuse delivered into the river must be in the same proportion, while, on the other hand, the quantity of water abstracted, both above and below Teddington, by water companies has diminished more and more the amount of the diluting and scouring fluid, leaving the remainder more and more charged with foul ingredients. For sake of argument, let it be supposed that the whole stream of the Thames which is now delivered over Teddington Weir were abstracted, what would be the consequence?—The tides would then return on the flood precisely the same quantity they took away on the ebb, and probably the very same water; and it is easy to conceive, under such circumstances, how soon the state of the river would become insufferable. Now, if taking away the whole would constitute so palpable an evil, taking away one-half or one-third would only be creating an evil less in amount in these proportions; or we may put the question in another point of view—suppose that in lieu of a moveable dam of tide water at Blackwall, there was a solid weir there, and that no fresh water was delivered at Teddington into the fresh water lake, so created and extending from Blackwall to Teddington, it would be manifest how soon such a lake would become thoroughly foul and pestilential, and in either case it must be seen how vast is the importance to London, that the volume of water delivered at Teddington should be preserved *intact:* the quantity delivered in summer weather amounts to about three million cubic yards per diem, while the contents of the lake, which has just been assumed as extending to Blackwall, may be estimated roughly at 130 millions of cube yards, and therefore requiring 43 days' delivery for its entire replenishment; but if we were to suppose one-third of the supply to be taken away above Teddington, it would require 65 days to replenish the lake. The health and comfort of the Metropolis, I conceive, so materially to depend on keeping what may be called the fresh water tidal department of the river (or that extending from Teddington to Blackwall) as pure as circumstances will permit of, as to impose the necessity of obtaining our supplies of water for domestic purposes from every other source rather than the river itself; and I think it may be shown that the waters which the Lea and the Darenth rivers discharge into the Thames below Blackwall yield about 17 millions of cube feet per day,

or more than double the quantity now supplied to London. Further, I conceive that were the bed of the Thames below Teddington deprived of its usual supply of land water, it would gradually silt up, and that the navigation downwards would become seriously injured. I object to taking the water of the Thames for the use of the Metropolis, because as good or better may be obtained at a much higher level and shorter distance off; and that, were all other circumstances indifferent, the water of the Lea is to be preferred to that of the Thames. From the River Lea, at a height of 148 feet above Trinity mark, and at a distance of only 14 miles from the skirts of London, a large supply of water may be obtained; whereas the height of the river Thames at Mapledurham is but 112 feet above Trinity mark, and at a distance of 40 miles from the outskirts of London; so that for Thames water we must go three times the distance and receive the same at an altitude less by 36 feet. Capt. Vetch.

22. Are you not aware, that in the northern districts of England the practice is extending of taking the surface waters for the use of towns?—I am aware that of late years the system is extending of storing surface waters for the supply of the northern towns, and that there are now several Bills before Parliament for such purposes. The plan pursued appears to be that of throwing dams across upland valleys, and so forming artificial lakes, and storing rain-water that would otherwise run to waste, the method is similar to what has been extensively resorted to in this country for the supply of water to our canals, and which I have seen practised in foreign parts (where the rains are periodical), for the supply of towns, farms, and factories; and where the necessary tanks are deep and extensive, the water is preserved clear, and is often superior to river water.

23. Have you had opportunities for observation, as to the surface for gathering grounds within 20 miles of the metropolis?—The surface strata within 20 miles of London are generally of an absorbent nature, being chiefly composed of beds of chalk and sand, which readily receive the rains and convey them to subterranean reservoirs. The portions of retentive soils within 20 miles of the metropolis, such as the blue and plastic clays of the London basin, as far as my observations go, are of limited extent, and being in the vicinity of arable land and a thick population, not available to any important extent of the object in view, and thus, though the strata within 20 miles of London are well stored with subterranean waters, which may be obtained by driftways, the surface is not favourable, in my opinion, for the storage of rain-water: there is, however, no doubt that much water that now runs to waste in winter may be saved for summer use, by throwing dams across some of the deeper valleys drained by the tributaries of the rivers Lea and Colne, and where, if even leakage should take place in reservoirs so formed, the escape of water would serve to augment the supply of many useful springs elsewhere. I am induced also to believe, though I cannot speak decidedly, that considerable quantities of water might be stored on the area drained by the Mole and its tributaries above Betchworth.

Henry Marten, Esq., examined. Mr. Marten.

1. You are, I believe, an engineer?—I am.
2. With whom did you serve your time?—With Mr. Wicksteed, the

Mr. Marten. engineer of the East London Water Works; whilst with him I assisted in the construction of the Hull Corporation Water Works, and was afterwards appointed by him to see his plans carried out for the construction of the Wolverhampton Water Works.

3. Since their completion have you had those works under your charge as resident engineer?—I have.

4. Will you describe the works?—They are situated at Tettenhall, a small village about 2 miles from Wolverhampton; the supply is drawn from the new red sandstone formation, and is forced from a depth of about 120 feet below the surface of the ground, over a stand-pipe 180 feet in height, the top of which is about 100 feet above the highest part of the town. They were commenced in 1845, and were wholly constructed, both in their mechanical and distributory arrangements, for carrying out the principles of the intermittent supply.

5. What is the quality of the water?—Since we have been giving a supply there has been no analysis of the water made, but the Wolverhampton Company originally decided upon it in consequence of its having been found by Mr. Aikin to be the best of 12 samples from the neighbourhood. Sandstone-water generally ranges from 16 to 21 degrees of hardness; and, as Mr. Aikin stated this to be singularly free from carbonate of lime, I believe it to be of a good average quality.

6. Has there been recently any change in the mode of water supply?—Yes. The intermittent system continued in force about 2 years from the time of opening the works early in 1847, but the company found the encouragement they met with under this system so extremely limited, and the objections raised against it so numerous, that they at length determined to abandon it; and early last year they introduced the method of constant supply. The change has met with decided success; and, to show the unpopularity of the intermittent system of supply, although the houses within the district commanded by these works number upwards of 7000, yet, during the period the company endeavoured to urge its adoption, they did not obtain more than 600 customers, or an average of 26 per month. On the adoption of the constant supply, however, an immediate increase took place, so that, in the 12 months during which it has been in operation, our customers have increased from 600 to more than 1750, or at the average rate of 96 per month. I should observe, that although the system of constant supply was introduced early in 1849, yet, being tried as an experiment only, it was not officially announced until the 1st of January this year. Notwithstanding this disadvantage, however, the ratio of increase under this system has been 270 per cent. greater than under the old plan. The above facts may be taken as a fair test of its superior adaptation to the domestic wants of the public. The non-success of the intermittent system is not attributable to any want of canvassing, as every house in the district was visited during the time it continued in force, and great exertions were made to obtain customers.

7. Will you state some of the particular facts with regard to the intermittent supply which came under your notice, and which led you to adopt the constant system?—We found that people felt little inclined to go to the expense and inconvenience of erecting tanks in which the water was to stagnate during the greater part of the day, when, with a little extra exertion, they could always draw a constant supply fresh from the pumps. In many places, in the more densely populated parts

of the town, there was no room on the premises for the erection of a tank, and when, in consideration of these circumstances, the company did not enforce the rules in this respect, it was found to be a great inconvenience to wait the particular times and seasons when the water might be turned on. In this case also the necessity of making use of the various domestic vessels (which could ill be spared) to hold the day's supply was felt and complained of as a hardship. The intermittent system also gave great dissatisfaction in those districts which did not receive their supply until the afternoon; these complained that they did not obtain the same advantage as their more fortunate neighbours, who received their supply in the morning. These instances illustrate the principal classes of objections raised against the intermittent system, and all of which more or less retarded its progress, and at last led to its abandonment. Mr. Marten.

8. Then, commercially considered, looking solely at the interests of a new Company, the intermittent system of supply for such a district is erroneous?—Decidedly so; in some towns, where it is exceedingly difficult to obtain good water, this system may no doubt have met with general adoption; but in a town like Wolverhampton, built upon the sandstone, and where water of a tolerably good quality may be obtained at a moderate cost, it can never succeed, the public will not be troubled with it. In the one case the public must, from necessity, put up with the supply provided; on the other it is a matter of choice whether they take it at all. I found that under the intermittent system parties only took the water where they could not do without it, whereas, under the constant system, they are often supplied for convenience sake, where there are good pumps and soft-water cisterns on the premises. Another inconvenience attaching to the intermittent system of supply arises from the water during the greater part of each day lying stagnant in all the sub-mains or service-pipes; this is a matter of material importance in all water which does not readily precipitate a protective coating on the inner surface of the pipes, as, upon being confined a short period, it acquires a disagreeable taste, and becomes highly discoloured by the absorption of a quantity of oxide of iron; this is especially the case in sandstone-water, and is a cause of much dissatisfaction, and requires, under the intermittent system, that the services should be washed out every day before the supply is given to the houses. This, of course, occasioned a great and useless waste.

9. Has it not been argued that this stagnation of the water in the pipes under the intermittent system is an advantage rather than otherwise?—Yes; it has been stated that "the pipes then become additional settling reservoirs." (See answer to question 4515 in Evidence before Health of Towns Commissioners, 1st Report.) Setting aside the fact that water so impure is actually so supplied as to require additional settlement, stagnation in the pipe will still be of no avail, as, if the pipes *are not* washed out previously to each supply, the whole of the sediment must be again stirred up by the incoming water, and driven into the tanks of the houses to be supplied. If however the pipes *are* washed out, the whole advantage of the settlement is likewise lost, as the fresh water from the mains in driving out the sediment will likewise drive out the clear water with it, and its place and the consumers' tanks will be supplied with water in which the process of settlement has still to be

Mr. Marten. completed. No advantage therefore can possibly be derived from the intermittent system on this ground, even in those waters where a temporary stagnation may not be a material evil. At Wolverhampton I found this a great disadvantage.

10. Before the change in the mode of supply took place, what was the daily rate of consumption?—The average gross consumption under the intermittent system was 128 gallons per house per diem. By gross consumption is meant the daily average of the whole quantity of water delivered and distributed amongst the tenants of the company independently of the purpose for which it is used. It includes therefore not only the domestic supply, but the proportion used by large consumers, brewers, manufacturers, &c., and the quantity used for street-watering, sewer-flushing, and waste. Hitherto in comparing the water supply of one town with another it has been customary to refer to the gross average consumption as a standard to test the relative merits of the "domestic supply." This however can never be ascertained by a comparison of the gross consumption, as the domestic supply proves but a small item in the quantity, and a town with a very much larger gross consumption may not receive nearly so good a domestic supply as one in which the gross consumption is much less. Thus, for instance, the gross consumption supplied by the London companies is very large, larger I believe than in any other town in the kingdom. The domestic supply however by no means follows the same proportion; and I believe, on the proper deductions for large consumers, waste, &c., being made on the gross consumption, it would be found that there are many provincial towns which receive a very much better domestic supply. From various observations I have been enabled to make, and the accurate accounts kept at Wolverhampton of the water delivered, I estimate the gross consumption of 128 gallons per house per diem may be divided into the following items:—

	Gallons.
To street-watering and town purposes . . .	20
To trades and large consumers	42
To washing out service-pipes, waste in houses, &c. .	31
To "domestic supply" (that is, to water actually *used* for various domestic purposes) . . .	35
Total	128

11. What has been the rate of consumption since the change?—Since the change the average gross consumption has been gradually decreasing, and during the last three months has not exceeded 79 gallons per house per diem, thus presenting a decrease of 39 per cent., as compared with the consumption under the intermittent system. This great decrease is doubtless partly owing to the water required for street-watering and for town purposes, and for trades and large consumers, not having increased in the same ratio as the number of houses.

Of the total decrease of 49 gallons per house per diem, I estimate that 22 are due to this cause, and allowing the same amount of water to be actually used (35 gallons per house per diem) for domestic purposes, under the present as under the intermittent system, the saving of waste

in the domestic consumption, washing out pipes, &c., will be 27 gallons per house per diem. Mr. Marten.

The following statement shows the amounts due to the various items of consumption under the constant system, which make up the total gross consumption of 79 gallons per house per diem.

	Gallons.
To street-watering and town purposes . . .	7
To trades and large consumers	33
To washing out service-pipes, waste in houses, &c.	4
To "domestic supply," that is, to water actually used for various domestic purposes	35
	79

12. Will you state some of the particular causes of waste which you found to accrue under the intermittent system?—When the supply was intermittent people drew much more than they actually required, in order to meet any contingency that might arise before the next supply came on. Now, however, having the water always at command, they draw only the quantity really necessary for domestic purposes. Ball-taps also would frequently stick and be out of repair, so that the water would be running away full bore the whole time it was turned on. The common practice of leaving the taps open, so that parties might have the first intimation of the water being turned on, was also a great source of waste, the taps being frequently neglected. At the Hull Water Works, constructed on principles similar to these, but where the intermittent system of supply is still continued, this is found to be very much the case. The engineer, writing on the 26th December last to the 'Hull Packet' in reply to some complaints as to the insufficiency of the supply, states that "in the summer-time it (the water) is turned on at 6 A. M., but later at this season, as the inhabitants are not up to receive it at that time, and leave the taps running to waste *for an hour or more* before they get up; even as it is, a great quantity of water is wasted in this manner." This, like the stagnation of the water in the pipes, has also been urged as an advantage afforded by the intermittent system, inasmuch as the surplus will tend to keep the drains and sewers in a clearer state. A due consideration of the circumstances affecting the water supply and sewerage will, however, prove that no advantage is derived on this score, as, when the sewerage is perfect, the quantity of water used under the constant system will be ample to keep the drains free from deposit, and where the sewerage is defective, as is unfortunately the case in most towns in the kingdom, a wasteful supply is only a great public nuisance.

13. What is the class of houses you supply?—We supply houses of all classes, but 50 per cent., as in all manufacturing districts, are under 10*l*. rental.

14. What is the proportion of trades to large consumers?—At the time we adopted the constant supply system, the trades and large consumers numbered about 20 per cent. of our customers; they now number 16 per cent.

15. Did not the former excess of water running to waste very much add to the dampness of the town, as there are no dains in Wolver-

Mr. Marten. hampton?—Yes, very much so, especially in the small ill-paved and ill-drained courts attached to the houses of the lower class. The constant opening of the cleansing plugs in the streets where there were no good gutters or sewers was very inconvenient.

16. Will you describe whether any serious difficulties or obstructions have been found in making the changes?—I have found no serious difficulty or obstructions in introducing the constant-supply system.

17. Will any alterations or additions be necessary in the pumping department?—Yes, in this department it will be necessary to construct an elevated reservoir, our head to supply the town being at present obtained by forcing the water over a high standpipe only. This, in principle, is exactly similar to a minute reservoir, capable of holding a few gallons only instead of one or two days' supply, but is subject to many practical inconveniences. The supply of the town, in this case, depends entirely from minute to minute upon the mechanical perfection of the engines, and the care and steadiness of the men employed to work them. The springing of a single bolt, or a very slight accident to certain parts of the machinery, may, in this case, entirely suspend the supply of the town for a very considerable period. The standpipe system is also a very expensive plan, the engine having to be worked, or to be in constant readiness to work, at a moment's notice, both day and night. This is necessary not only under the constant but under the intermittent system of supply, because, although all the houses may be shut off, the pressure has still at all times to be kept up in the mains to give a supply in case of fire. It is necessary on this account to employ a double set of enginemen and stokers, and to incur expensive overtime when any little repair has to be executed. To show, also, in a still clearer light the expense of the standpipe system: at these works the engine is of sufficient power to raise the whole supply for a week's consumption in 30 hours, whereas, by having no other elevated storage-room than that contained in the standpipe, the engine is obliged to be worked during 168 hours to deliver this quantity. With a standpipe only the speed of the engine has to be altered and regulated with every variation of the draught on the mains. And again, although the mains are constructed to deliver a very much larger quantity than the engine can pump at any one time, the parties supplied can derive no advantage from this, as they can never draw the water faster than it is pumped. Thus the standpipe system limits the variations of draught that can take place in the mains to the speed of the engine, instead of the velocity due to the head to which the water is actually raised. The expense and inconvenience of the standpipe system was found to be so great at these works that it was determined to construct a reservoir, even had the company contemplated continuing the intermittent plan of supply; and wherever the construction of an elevated reservoir is possible, and there are very few cases in which it is not, preference should be given to this instead of the standpipe.

18. What alteration did you find necessary in the distributory department?—I find that very little alteration is necessary. The leading main laid down for giving the intermittent supply will be amply sufficient for giving the constant supply. The capacity of the submains and services will also be ample; these latter were all calculated for delivering the whole of the day's supply in the very small period of the 24 hours, and there can, therefore, be no doubt but that they will be

sufficient to deliver the less quantity required by the constant supply, especially when its delivery is spread over the whole day. The only material alteration I propose making in this department is to connect as many of the present dead ends of the pipes as possible, so as to keep up a free circulation. The advantages of this alteration will be more readily seen by considering the plan at present adopted in laying down water-pipes for the supply of a town. The line of the principal main having been marked out, the submains and services are branched out from it in various directions like the boughs of a tree from the main trunk. The consequence of this arrangement, which is a necessary evil under the intermittent system, is, that a great many dead ends are formed, in each of which there is constantly a quantity of water stagnating, which soon becomes unfit for use, and must be washed out at a great waste of water. Mr. Marten.

19. You state that the mains laid down for giving an intermittent supply will be amply sufficient for giving a constant supply: have you made any experiments on this point, relative to the draught on the mains at Wolverhampton during various periods of the day?—I have lately done so, and present the results of these experiments in the following table, which is also confirmed by the results of a similar series of experiments conducted in other towns in whcih the constant supply is in operation.

The first column shows the period between which each observation was made; the second the percentage of the whole "gross consumption" for the twenty-four hours delivered between those periods; and the third the number of hours which would be occupied in delivering at that rate the whole consumption for the day.

The results stated in the table are the average of a series of observations extending over the period of one week.

Time.	Percentage of gross consumption.	Time which would be occupied in delivering gross consumption.
Between 6 and 7 A.M.	3·735	26·77 hours.
" 7 " 8 "	5·209	19·19 "
" 8 " 9 "	6·192	16·14 "
" 9 " 10 "	6·438	15·53 "
" 10 " 11 "	7·076	14·13 "
" 11 " 12 "	7.764	12·88 "
" 12 " 1 P.M.	5·995	16·68 "
" 1 " 2 "	5·946	16·82 "
" 2 " 3 "	6·388	15·64 "
" 3 " 4 "	7·862	12·72 "
" 4 " 5 "	5·209	19·19 "
" 5 " 6 "	6·290	15·90 "
" 6 " 7 "	3·685	27·13 "
" 7 " 8 "	5·012	20·00 "
" 8 " 9 "	3·047	32·81 "
" 9 P.M. 6 A.M.	14·152	68·26 "
	100·000	

From the above table it appears that the greatest consumption takes place between eleven and twelve in the morning and three and four in the afternoon, during which periods the draught reaches to nearly 8 per cent.

Mr. Marten. upon the gross consumption, and would require the mains to be of a capacity to deliver the whole supply for the twenty-four hours in twelve or thirteen. The greatest draught takes place on the Saturday, when there is the most general cleaning up. On the forenoon of this day, between eleven and twelve, the draught reached to nearly 11 per cent. of the day's consumption, which would require the mains to be of a sufficient capacity to deliver the whole consumption in a little more than nine hours. This is the greatest rate of consumption observed. Now, under the intermittent system, it has been the general practice to lay down the mains of sufficient capacity to deliver the whole day's supply in six or eight hours, so that they will be amply sufficient under the constant system, even when the draught is at the greatest.

20. You are of opinion also that, with a free circulation, less oxidation goes on?—Yes; oxidation appears to take place in proportion to the length of time the water lies stagnant against the sides of the pipes; but by the proposed arrangement, the whole of the pipes being connected together wherever possible so as to form a great network, a free circulation is kept up, the water always tending in all the pipes to the point of greatest draught. Thus, also, a *uniform quality* of water is maintained throughout the whole town, and the pipes, being fed at both ends, may be made proportionably smaller.

21. You think, therefore, that it is very important to have the circulation active?—Yes. It presents many advantages, and in those cases in which I have applied this method it has answered admirably.

22. Is there any other alteration you propose making in this department?—I propose to make the guard-cocks on the submains and services much more numerous than under the intermittent system, placing them at an average distance of not more than 50 yards apart; all the cocks should be double-faced, so as to shut off the water either way. This arrangement overcomes a difficulty that might sometimes prove of consequence, were the constant supply given through the old intermittent pipes, as in this case the repair of a single pipe, or the laying on of one fresh house, might occasion the stoppage of supply to an extensive district. Under the proposed arrangement, however, this will not be the case; as, by shutting down the guard-cocks on either side of the place where it might be necessary to execute any repairs, &c., the tenants in the immediate neighbourhood only would be deprived of the waters, and could in no case have to go more than a few yards to obtain a temporary supply. The remainder of the district would of course be supplied through the other ends of the pipes.

23. What will be the cost of the proposed alterations?—The cost of the above-mentioned alterations, for giving the constant instead of the intermittent supply at Wolverhampton, will not exceed 6*d*. a-head of the population within the district. This is exclusive of the reservoir, which would have been essential to the continuance of the supply under the old system; including this, however, the whole cost will not exceed 2*s*. per head of the population. I think there are very few towns in which the cost of the alterations necessary for the introduction of the constant-supply system will exceed 2*s*. per head of the population, and that in general it will be found much under this amount.

24. What would be provided under that charge of 2*s*. per head?—Where none have been previously provided it will cover the expense of

providing the necessary reservoirs and the alteration of the street-mains, Mr. Marten.
with the introduction of the additional stop-cocks, and will be sufficient to prepare all the internal house-fittings for the reception of the constant supply. In almost all towns in which the intermittent supply is in force, the fittings are in a very defective state. The water being on so short a time, it has been thought hardly worth while to see that these are kept in good repair; and consequently they will, as far as the taps and stop-cocks are concerned, require almost a complete renewal. The useless piping and tanks and old metal, however, which may be removed on the introduction of the constant system, will more than pay for these matters.

25. Will the additional outlay above mentioned increase the cost of raising and distributing the water and the charge to the consumer?—No. Had the works at Wolverhampton been constructed at first with a view to carry out the constant system, there is no doubt they could have been made at considerably less cost, as it is, however, the additional outlay will not require any increase of charge to the tenant. The interest of the money so spent will be fully saved in the reduction of the enginemen and turncocks' wages-account, in the smaller consumption of engine-stores, in having to pump less water, and in being enabled to deliver it in less time by having a reservoir, and by the reduced wear and tear of the cocks and pipes. There will also be a great economy in all future extensions of pipes.

26. You state your belief that the wear and tear of street-cocks will be less under a system of constant supply. Have you observed any difference in the wear and tear of these in streets of much traffic compared with those of little traffic?—I have not observed any perceptible difference between the wear and tear of the valves of cocks placed in a street where there is much traffic as compared with the *valves* of those placed in streets of less traffic; but in the former case the iron boxes which cover them are more subject to injury, and we find them sometimes filled with dirt or "sludge" from the road.

27. Supposing the levels to be the same, will not the strain and damage of pipes and taps from the hydraulic jerks be greater on the intermittent than the constant supply system?—Yes; because under the intermittent system the whole pressure of the works is brought to bear upon one particular spot with a suddenness which often causes considerable damage from the recoil. Under the constant system, however, the pressure will only vary by imperceptible degrees, and there can be no jerks on the mains and pipes. In the houses none of the common bib-taps should be allowed to be used, but should be of the kind termed "screw-down," as they are every way better adapted for high pressure, and do away with all recoil.

28. What are the variations in height, or different heads of pressure, at which the supply is delivered at Wolverhampton?—The greatest pressure is about 200 feet, and the least 100 feet.

29. What is the size of the highest house where the delivery takes place?—The South Staffordshire Hospital, which contains accommodation for 200 patients, is the highest house in which the supply is given, the top of which is about 80 feet below the top of the standpipe.

30. It appears that Wolverhampton varies in level. Have you found any occasion to "withdraw the supplies to wasteful districts, and those

Mr. Marton. of a very low level, for the purpose of securing a more full discharge at other portions of the town at high elevations?"—No. I do not understand the term "wasteful districts:"—waste and leakage imply want of repair; and when this is the case, these districts should at once be put into a proper state for receiving a supply, and not attempt a half measure by wire-drawing. When all the pipes and taps are in a proper state of repair, as they should be, the draught on the mains under the constant supply is exceedingly regular. Wire-drawing might be necessary where the constant supply is given through the old fittings erected under the intermittent system, and from which the leakage must be very great.

31. Are any, and what expedients used to adjust the pressure and rate of delivery where there are considerable variations in the heights?—I have not found it necessary to make use of any particular expedients at the Wolverhampton works to adjust the pressure and rate of delivery, excepting that in the lower parts of the town where ½-inch service-pipes are inserted, in the higher parts ¾-inch are used. A stop-cock is inserted in each house service, so that, if any inconvenience should be felt from the pressure being in any part too great, the rate of delivery can be reduced by partly shutting the cock.

32. Under the constant supply would there not be various advantages in using the hose and jet for washing the surface of the streets and house fronts?—Yes, it could be very readily applied, and would be very effective where the paving is good, in washing the surface of the streets and the footways. We occasionally wash down the front of a large inn in the market-place in Wolverhampton in this way, and it answers very well, completely removing the dirt.

33. Then you have no reason to doubt that by the use of similar means the whole face of the houses in a town might be changed from an appearance of dirt to cleanliness?—No doubt they might be washed in this way.

34. Have there been fires in Wolverhampton where these jets have been used?—It was used at one fire, and by its ready application and the great force of the water, was the means of preserving a large amount of property from destruction; it did its work so completely, that the owner afterwards informed me that he thought the water had damaged his property rather more than the fire.

35. The jet then was even more than adequate?—Yes. We found, on trying some experiments for the satisfaction of a Birmingham fire-office, that we could throw the water from a jet-pipe half as far again as it could be thrown by the fire engine, which it took 14 or 15 men to work. We can throw the water about 70 feet from the ground with a ¾-inch jet.

36. What is the expense of the service-pipes as now laid down on the constant system of supply as compared with the expense to tenants arising from cisterns, &c. under the intermittent system?—I find the cost of laying down the lead service-pipes from our mains in the streets into the houses, together with the cost of stop-cocks, bib-taps, &c. for giving the constant supply, averages 16*s.* 6*d.* per house. This is the average made upon 600 houses laid on by the Company, and taken consecutively as the entries appear in the Company's books, the total cost being 491*l.* 12*s.* Had tanks been required to these houses as

under the intermittent system, the extra cost would have been at least 22*s.* 6*d.* per house. The extra cost, therefore, on this head, of which these houses are disburdened by the introduction of the constant supply, is 675*l.* Whence from the above facts it will appear that the cost of laying on under the intermittent system is 136 per cent. greater than under the constant supply. Mr. Marten.

37. What is the smallest sized pipe you use?—I have not been in the habit of using anything smaller than ½-inch, although I know such to have been the case at other works. I find a ¾-inch branch main more than ample to supply courts containing 13 houses.

38. How many do you think you have supplied from a ¾-inch main? —I do not remember an instance of more than 13 having been supplied from a single ¾-inch pipe, but I should not hesitate to supply 20 from the same pipe.

39. Under the old system of supply, what sized pipe should you put down for the service of courts like this you have mentioned?—I cannot say what would have been the requisite size in this case, as under the intermittent system many parties left their taps running the whole time the supply was on, so that, to give all a due supply, the pipe would have been required of considerable dimensions. Under these circumstances it is the practice to lay down a 1½-inch or 2-inch pipe for the intermittent supply.

40. Have you used iron service-pipes instead of lead?—Yes, occasionally; but I do not prefer them, as I have found them more uncertain and more liable to damage from frost than lead pipes. They are not so readily fixed as lead, and in some situations a rapid and destructive corrosion takes place which eats them through. I have seen some iron tubing glazed on the exterior, but the cost is considerably increased in this case.

41. Will you state what would be the expense of cisterns for first-class houses with water closets, and the cost to tenants of each class of house for butts?—I have no means of telling precisely the average cost of cisterns, &c., to each class of house, but it will vary from 1*l.* up to 50*l.* or 60*l.*, in accordance with the size of the building and the completeness of the fittings.

42. Will you contrast the expense of outdoor tanks, &c., with such a system as that of Ridgway's fountain sinks, supposing them carried into the interior of each room?—A Ridgway's fountain sink might be fixed complete in each room of a house for the same sum as is now often spent in the erection of the cumbrous apparatus required under the intermittent system.

43. Also in the case of first-class houses, whether baths and fountain sinks might not be put up at the same expense as these tanks and other external apparatus?—I think so. The expense of tanks, &c., in houses of this description is often very great, and they are obliged to be placed in such out of the way positions that the expense of repairs and cleaning becomes considerable.

44. Have you had opportunities of observing the liability of the water to pollution from exposure to soot and dirt?—Yes. Where the tanks are situated within the house, the water soon loses its freshness and acquires a slimy character, and when exposed outside it rapidly accumulates on its surface a coating of the impurities invariably carried in

Mr. Marten. the atmosphere of towns. In some waters exposed in this manner, fermentation quickly appears to take place, succeeded by an unwholesome vegetation, and lastly, the development of animal life. Filtration may clear this water, but cannot restore it to its original state. In the summer time, and during warm damp weather, water exposed in butts becomes rapidly foul, and this takes place quicker in old than new tanks. I know an instance in which a butt supplied on the intermittent plan, although washed out three times a week, yet could not be kept clean; at the end of the second day a green scum had risen to the surface of the water, and there were a quantity of little red worms, and I was informed that several other tanks were worse than this. This occurred in the neighbourhood of London. At Wolverhampton, I have observed a thick yellow scum like floating sponge given off by the water when retained in tanks, and the water has acquired an unpleasant taste. In some situations water is rendered still more unhealthy by its power of absorbing noxious gases, so that people not only live and breathe in a poisonous atmosphere, but are also required to drink it condensed in the water.

45. Since the change of system have these complaints ceased?—Yes.

46. You have met with little real occasion for the retention of tanks?—No. At present I only retain them for waterclosets, which need never be more than boxes about 18 inches square and 1 foot deep. The object of these is to cut off any direct communication between the main and the soil-pan, so as to prevent the possibility of any drawbacks. In the supply of boilers, &c., where there is no underground cistern or jacket-pit, I also require them. I do not think they need be retained for any other purposes.

47. In respect to the distributory apparatus, what sized pipes would suffice, in your opinion, for street service?—As regards capacity, I think that 2-inch pipes would be sufficient, but I never lay less than 3-inch, as there is scarcely any difference in the cost of these and the smaller size. This size also leaves a margin for the supply of any parties who may require a large consumption after the pipes are laid.

48. Did you lay down the pipes in the centre of the streets?—No; we have generally had to occupy either one side or the other, in order to leave the centre of the road for the construction of the intended sewers.

49. Will you estimate what the cost would be if you carried the pipe close to the house instead of the present system?—Supposing the case of houses in a street of an average class, say roadway 30 feet wide, with footpaths 6 feet wide, and the houses of 21 feet frontage, and 30 feet deep to the wash-houses. Then I estimate the cost of laying down the cast-iron service-pipe in the centre of the street, with cocks, fire-plugs, &c., complete, and the cost of a ½-inch lead branch pipe, with taps, &c. complete, will be 3*l.* 3*s.* per house. If there was a line of cast-iron service-pipes down each side of the street, the cost per house would not be increased, as the saving in branch pipes would pay for the otherwise increased outlay.

50. Also, what would it be if you had the distribution like back drainage at the back of the houses, and also how much would it save the tenant's cost on an average?—In this case I estimate the total cost of iron service and lead pipes, &c., at 27*s.* per house, and that this arrange-

ment would effect a saving of 38*s.* per house, of which the saving to the tenant would be 22*s.* I make this estimate upon the case above stated. I think the system of back supply would be found of great advantage in poor neighbourhoods, as, under the present plan, the poorer class can only afford to have the tap brought just through the front wall, so that the principal part of the water used has to be carried to the back premises. The system of back supply would do away with this inconvenience. Mr. Marten.

51. Will you give a return of the cost at which, supposing the whole service of the town had to be laid down afresh, you could lay it down for front supply; also the cost for back supply; showing the distinct cost of mains of service pipes, and the total cost to each tenant contrasted with the system of supply from the front of the street, and compared with the mode adopted in the metropolis?—Passing from the separate case above stated, and supposing the whole service of the town had to be laid down afresh, at present prices, it could be done on the system of front supply, at 63*s.* 6*d.* per house, of which the mains would cost 26*s.* per house, the service pipes 21*s.*, and the tenants' branches 16*s.* 6*d.* per house. On the system of back supply it could be done for 47*s.* per house; that is, supposing we had had powers to pass through the private property, both of those who did and those who did not take the supply, in the same manner as we have power to lay pipes in the streets. Of this sum the cost of mains would be 26*s.* per house, of services 14*s.*, and tenants' branches 7*s.* per house.

52. How much would the earthwork cost of that amount?—In the first case 5*s.* per house, and in the second, for back supply, 3*s.* 6*d.* per house. I am speaking of Wolverhampton.

53. How much of that cost would you save by combining the laying down of the return pipes at the same time as the supply pipes?—If both the supply pipes and the return pipes could be laid in the same trench and at the same time, there would be only one excavation to make instead of two, and the saving would therefore be equal to the cost of the earthwork per house for the supply pipes.

54. If you were to lay down a constant system of supply, with the substitution of soil-pans, &c., for cesspools, would you not expect that it would be necessary to have a man to look after the taps, the tenants' service pipes, &c.?—Yes. This department has hitherto been much neglected, and the tenants have often been put to considerable inconvenience and damage, first from want of a proper inspection of their supply-pipes, &c., so as to have them always kept up in good repair; and, secondly, by the attempts of ignorant and unqualified workmen to repair them. I think an inspection of these internal fittings, at stated intervals, by properly qualified workmen, would be a great advantage.

55. That would be economical to the tenants themselves, then?—Undoubtedly; they would be certain of having the work well done and well looked after.

56. From your knowledge of a London system of supply, and your practical experience of the change of the system of supply from an intermittent one, do you perceive any difficulties other than those you have stated in changing the system of supply in London from the intermittent to the constant supply?—I do not; as a rule the mains laid down for giving the intermittent supply will be found amply sufficient for giving

Mr. Marten. the constant supply, the submains and services always so. The idea that the pipes must be of sufficient capacity to allow all parties to draw from them at the same time is contrary to all experience, and in practice it will very rarely happen that so many as one-tenth of the population are drawing water at the same time. The pumping machinery and reservoir of the intermittent plant will also be sufficient for the constant supply, as less water is used under this system.

57. Then, keeping in view the system of supply in the metropolis, we understand that you are clearly of opinion that it is by no means necessary to the constant supply that the works should have been originally constructed for it?—I am of that opinion, and would only observe further, that before attempting to give the constant supply to any town which has long been accustomed to the other plan, I think it would be prudent that the whole of the works for so doing should be made perfect and complete. The town, on this being done, should be divided into districts, and the service-pipes and taps in each house put into a proper state for receiving the supply on the new plan, which should not be given in any district until these are proved satisfactory. Without these precautions, or some similar to them, in old towns, the constant supply would be deprived of a great portion of its efficiency. Little benefit can be derived from merely patching it on to the old system, but where it is determined to introduce the constant supply system the change should be thorough and complete. When, however, the necessary alterations are fairly planned out, previously to any change being made, and set about systematically, I do not think the slightest material difficulty can arise, and the increased domestic convenience afforded by this system, and the expansion it presents for sanitary improvement, will amply repay any temporary inconvenience in making the change.

Mr. John Roe examined.

Mr. Roe. 1. Were you not required by the Metropolitan Sanitary Commission in 1847 to gauge the run of water at given streets and sewers?—I was.

2. What was the result of your gaugings?—It is given in the following paragraph:—" It appears that in the second or third-rate class of streets, the run of water from the houses to the sewers is about 45 gallons per diem; but that in the streets of the first class of houses, all of which have water-closets, and all drain into the sewers, the daily run of water is, on the average, about 75 gallons per diem per house, except on the days on which the intermittent supplies are on, when the run increases in the third-rate streets from 45 gallons to about 78 gallons, and in the first-rate streets from 75 gallons to upwards of 100 gallons, during the day, affording an example of the waste incurred under that system. So far as the observations have proceeded, they are in corroboration of the opinion that the prospective estimate of a supply of 25 gallons per head of the population per diem, or 125 gallons per house, would effect all that at present appears necessary to keep a properly-devised system of house-drains and sewers of a town in salubrious action."

3. Have you since had the opportunity of observing your former gaugings and of carrying them further?—Yes, to some degree.

4. Was their correctness confirmed, or otherwise?—They were confirmed. Mr. Roe.

5. Will you state the result of your experiments as to the quantities of water?—In one long street the excess on water-days would average a depth during the year of 16 inches of rain over the area occupied by the buildings, gardens, and roads, or 22 inches over the area occupied by roads and buildings only. In another street the average would be 13 inches during the year in one case, and 21 inches in the other.

6. Your gaugings were, I believe, at the mouth of the sewer?—Yes, they were not gaugings of the butts, so I cannot say what was lost by permeation. All these experiments were tried on a gravelly soil, and much therefore would be lost in that way.

7. It has been stated that the loss on days when the water was not on was about one-eighth between the butts and the sewers?—That calculation is moderate enough; and when the water is on, the permeation of course must be greater.

8. Of course, in laying down new drainage works a great proportion of the expense is in earth-work?—The greater proportion of cost is in the material used, but the earth-work forms a considerable item in the total cost.

9. Might not water-pipes be laid down at the same time in general without double earth-work?—Yes.

10. Has it not been contemplated by the Works' Committee and by yourself that the superintendence of both should be under the care of one man on the spot?—Yes.

11. Did you not propose that the heads of sinks should be opened by only one key and one apparatus?—Yes.

12. Will you put in the form of apparatus you designed?—The drawings are in the office at Greek-street, whence a copy may be obtained, as they were ordered to be lithographed.

13. Then the business of one man, as contemplated, would be to cleanse the streets and courts by jet when it was required, and to be ready in case of any stoppage or disorder to set it right?—Yes.

14. Was not one mode of flushing by the removal of the cap of the house-drain and putting on the hose and cleansing everything by the discharge?—Yes.

15. Was it not contemplated that all the apparatus should be provided for under one rate?—Yes.

16. Do you see any reasonable probability of having such things carried out for a period of years, except by a common rate as a distributive charge?—No.

17. You are cognizant of the experiments illustrating the rapidity of the mode of cleansing by means of the jet?—Yes.

18. Do you think that either the water supply or house drainage can be carried out so economically separately as in combination?—I do not think they can.

19. Have you any doubt, as an engineer, that the like gain in efficiency and in economy which in drainage would be practically attained under the Metropolitan Sewers' Commission would be practicable also with regard to the water supply?—I have no doubt of it.

20. When you introduced flushing as a cheaper means of cleansing,

Mr. Roe. did you not expect to be obliged to have additional supplies of water for the purpose?—I did, and I applied to the engineer of one of the Water Companies to ascertain the prices at which they would furnish such additional supplies.

21. Did you not find that on days when there was an intermittent supply there was quite sufficient water?—Yes, without having occasion to purchase.

22. From your experience and knowledge, have you any doubt that your experience in this instance as to the available character of waste water for flushing is available universally by economizing the waste water on the days of supply?—I have no doubt of it.

23. Have you not carried out gaugings of the Fleet river at the request of the Commissioners?—In 1830 I began a series of gaugings in the Fleet sewer, and continued them at intervals to the time the Metropolitan Commissioners requested me to still continue them.

24. Did you observe any alteration on the days of water supply?—Yes, in a proportion very similar to what I have before stated.

25. What districts does the Fleet drain?—A large portion of St. Pancras; a portion of Islington; St. James Clerkenwell; and part of St. Andrew Holborn, and other districts below the point of observation.

26. What is the rate of discharge (in gallons) in the sewers in the street you mentioned in the New River Company's district, when the water was on and when there was no rain-fall?—The greatest flow observed was 160 gallons per minute.

27. What was the rate of run when the water is not on, and when there was no rain-fall?—Four gallons per minute.

28. In the River Fleet what was the rate of run at periods of time when there was no rain, and in days when the water was known to be on in the district?—The average rate of run during a month of dry weather, at the time when the flow was affected by the water-supply in the district, was 1,738 gallons per minute.

29. What is the rate of run at like periods of time in dry weather, and when the water is not on?—The water-supply appears to be on every day (except Sunday) in some portion or other of the district draining to the Fleet, parts of which are supplied by the Hampstead Water Works, and others by the New River. The rate of run, when not affected by the supply being on, was 756 gallons per minute.

30. What is the rate of run on days when there is rain? What is the rate of run on days when there is not rain?—The greatest quantity observed when rain fell was rather more than 800,000 gallons per minute. This was on August 1st, 1846; but this was not all that the Fleet was required to convey, had all reached it freely. But from its being too small at some distance above the point of observation, much water was backed up, causing the flooding of property to a great extent. The least rate of run observed during dry weather, at times when the flow was least affected (if at all) by house drainage, was 261 gallons per minute.

Mr. Stirrat.

Mr. *James Stirrat*, Bleacher, Paisley, *examined.*

1. Are you conversant with water-works in Scotland?—Perfectly.

2. Have you had occasion to notice those which derive their supplies from surface gathering grounds? More than any others.

3. At what places?—At Glasgow, Edinburgh, and Paisley, particularly. I was also seven weeks engaged by the Liverpool Corporation to give evidence in Committees of Parliament, and to examine the different streams on the Lancashire hills, whence they propose to derive a new supply of water. I find, as the result of my experience, that the purest and best soft water is *only* obtainable from lands lying on the primitive rock formations, such as green stone, granite, millstone-grit, &c. Rain-water from such districts, stored in large and *deep* reservoirs is as pure as it is practicable to obtain it, and the best in every respect for domestic and manufacturing purposes.

3*. Were not you the first individual who proposed this source of supplying Paisley with water?—I was the first to propose it in recent times, but the first individual who proposed it, so far as I know, was Lady Ross, the grandmother of the present Earl of Glasgow, who, about the year 1770, made an offer to the Magistrates and Council that, if they would make reservoirs and construct the necessary works, in the very manner which is now done, she would give the land gratis for the purpose; which offer they refused.

4. Of what degree of hardness is water obtained from such districts?—I am not accustomed to speak of water as to degrees of hardness, but am aware that as the quantity of mineral and saline matters held by water in solution is increased, so is the hardness. The water of the Clyde at Glasgow, for instance, contains on the average 15 grains per imperial gallon of such; whereas the new supply by gravitation from lands lying on the greenstone rock is so pure that less than two grains can be obtained only by the most minute chemical test. As simple a test of comparative hardness as I have used, is to boil two samples of water and test with a thermometer their comparative rates of cooling. The one which is purest invariably cools first.

5. How is Edinburgh supplied?—Partly from drainage off high grounds, and partly from the Crawley springs; the water there is harder than the new water at Glasgow or at Paisley, but softer than the water derived from the Clyde at Glasgow; but, in a dry summer, there is sometimes an inadequate supply. Companies have at various times, both at Edinburgh and Glasgow, been started to obtain fresh supplies from drainage alone, but they have been always thwarted by the old Companies, until the Gorbals Company in 1846, got a Bill for supplying the south side of the river Clyde, after great opposition from the old Company.

6. Having investigated the gathering grounds in Lancashire and in Scotland, is it not your general conclusion that the shorter the distance the water has to travel over the surface the less matter it has in suspension?—Certainly that is the case generally, although there are exceptions. Water flowing from high rocky districts is, as I have said before, very pure and soft, but as it generally comes on to more level grounds, where the more recent formations occur, such as lime chalk, iron, &c., it becomes more and more impregnated in its course

Mr. Stirrat. from springs and rain falling in the lower districts, and is of course less soft and pure. However, in other cases, particularly where a stream has its source in peat moss lands; such water, although much discoloured at its source, becomes more and more pure, from exposure to the action of the atmosphere, and becomes quite clear.

7. From Mr. Thom's statements and other early documents, was it not estimated that only $\frac{1}{8}$ of any given fall of rain was available, and has not subsequent experience concluded it to be much more?—Before investigations made by myself and others in my neighbourhood, Mr. Thom stated that it was altogether impracticable to supply Paisley in the way that is now done (that was in 1826), and again in 1835 he reported that as much as 18 inches *might* be available from the rain fall, and on this report the Company was formed; but now, after an accurate measurement of the available quantity deliverable to the town, it is found to be about 36 inches annually on an average of three years,* and the consequence is that the reservoirs are of too small a capacity to contain the floods; and although 50,000 of a population are supplied with as much as they choose to consume at all hours night and day, besides about 80 factories, comprising dye works, print works, &c., getting a supply varying from 1,000 to 150,000 gallons each daily, there is water wasted in the winter season, during floods, on an average to an extent that would give a supply to 20,000 more of a population.

We, the bleachers, printers, &c. whose works are on these streams, stipulated with the Company to have a supply to our works of *one-fourth* part of the whole water that might be found available from the drainage grounds intercepted by the water company, and that to be given off to us in a regular and uniform stream, and the quantity to be ascertained by a three years' measurement, and the average of these three years to be continued in all time coming, this was the reason of the measurements being made. I was appointed by the bleachers, &c., to see that it was done fairly by Mr. Thom, who was appointed by the Company. And we, (the bleachers, &c.) now find that during the four or five summer months, we have a regular stream from 20 to 30 times greater than before, and are protected from the winter floods which often did us much damage.

8. Then all subsequent experience goes to show this, that the quantity derivable from surface or gathering grounds is greater than was anticipated?—Most unquestionably it is.

9. In this case is it mere surface water which is derived, or do you derive any of it through land drain pipes?—All water is mere surface water in the first instance, and the only difference from that from drained land, that we have a greater *available* supply from any given fall of rain, because it comes more quickly off, and less evaporation takes place.

10. Then your opinion and experience is, that water does not lie on the surface where land is drained, it does not sink so far, and is more quickly delivered into a reservoir for distribution?—Yes, that is precisely what I mean.

11. Supposing a given quantity of land were drained how much more

* This *available* quantity was derived from an average fall annually of 54 inches.

Mr. Stirrat.

water would be likely to be obtained from it than it would yield if it were not drained ?—This depends on the nature of the subsoil, but in every case drained land will produce more *available* water than land that is not drained. I may here mention that we find uniformly that in high districts the fall of rain is greater than in low districts. At Paisley, the drainage lands are on an average about 400 feet above the tide level, average fall of rain 56 inches a-year. At Greenock Shaw's Water-works, 16 miles west from this, average height of drainage land about 600 feet, average fall of rain about 65 inches, available 42 inches. In our district, on the above data, the available rain on 100 statute acres is more than sufficient to give 20 gallons a-day to each head of a population of 10,000 persons. The fall of rain, therefore, varies very much in different parts of the island. In Cumberland, where there is a large extent of high table land, about 2,500 feet above the sea, the quantity of rain is found to be 150 inches annually, and in London it is only about 22 to 27 inches. It is an interesting fact that, when Sir Christopher Wren was building St. Paul's Cathedral, he set a rain gauge in the church-yard, which indicated a fall of 22 inches. Since his day, until the last 10 years, almost all the rain gauges have been of an improper construction, and most of them now kept are still very defective ; but it appears from recent observations that Sir Christopher Wren's rain gauge was a correct one.

12. It is stated that the rain gauge on the top of York Minster shows different results from that at the bottom of the building ?—No doubt it will, and must do from a reason that it is easy to explain.

13. How much could be obtained from a fall of 20 inches near London ?—It would depend on the soil on which it fell.

14. Have you observed the quality of the thorough drain water : we find upon getting analyses of surface waters compared with the thorough drain water, that there is generally less animal matter in it but that it is also generally much less hard than surface water ?—We have not had occasion to observe any such difference.

15. Have you altered your mode of filtering water of late ?—Yes ; at Paisley, Greenock, &c., there is only one filter bed of *fine* sand. But at the New Works to supply Glasgow, we adopted, at the suggestion of Mr. Smith, of Deanstone, an entirely new mode, viz., three filters : the uppermost composed of rough stones from the size of a hen's egg and upwards, taken from the bed of the stream, where the water is allowed to rest as long as possible ; and by the laws of gravitation these stones attract the light particles floating in the water, which are now seen to increase the size of these stones ; it then passes into a second filter made of coarse sand or pebbles about the size of a common pea and smaller, which intercepts the gross particles ; and lastly passes to a filtering bed of fine sand, and the consequence is, that the water is not only perfectly pure, but the fine filter which otherwise would have required washing once a week or so, works for six weeks or two months without the sand being removed to be washed and cleaned.

16. Do you get the water out as clear as spring water ?—Yes, perfectly clear.

17. Is there any peat in those gathering grounds ?—At Paisley, about 20 acres out of the 700 ; and at the Gorbals of Glasgow, somewhat less in proportion.

Mr. Stirrat.

18. Do you know any other gathering grounds where there is any tile-draining?—The Ayr and Kilmarnock.

19. Do they drain them?—Not the water Companies, but tile-draining is going on over the whole country more or less by the farmers.

20. Have you found any ineonvenience from farmers draining or manuring land?—No; I have taken notes of the quantity of water coming off the high lands into the Paisley reservoir, and find that on an average of years, seven-tenths of the whole quantity is collected, or, in other words, flows off the high grounds in 27 days per annum. We have found no differenee in the quality of the water from agricultural operations.

21. What is the extent of these reservoirs?—There are at Paisley in all three reservoirs, whieh eontain 49 million cubic feet (49,000,000) having 790 aeres of drainage ground.

In order to store up the flood-waters of a wet year so as to make up the defieiency of a dry one, and so as to lose no part of such floods, I find by the experienee of the fall of rain in this district for the last 16 years, that storage room is necessary for two-thirds of the whole available quantity, that is for 24 inches from the whole drainage grounds; our reservoirs are, therefore, too small for the extent of drainage.

22. What is the greatest depth of your storage reservoirs?—At Paisley, 32 feet, where drawn off; and at Glasgow New Works, 51 feet: and we have the means of drawing off water at four different depths at both works.

23. How deep do you find plants grow?—I have found in this distriet that no aquatie plants grow where the water is 12 feet or more in depth, but that at a less depth they do grow and accumulate very fast. In a small reservoir at my own works, depth 8 feet, extent half an acre, I was much annoyed with such plants; but last year I got by advice a pair of swans, and they cleaned it completely in a few weeks, and it has been quite clean ever since, they would take no other food while these plants lasted.

24. One general evil in the storage of water is, that where the water is exposed to the sun, vegetation grows and animal life ensues. It has been suggested to roof the reservoir where that can be managed, and the question is whether a floating roof eannot be constructed?—We have had under consideration the roofing of the filters and distributing tank, which are liable to the objeetion you mention, and which can be easily done at a small eost; but as to covering or roofing the storage reservoirs that is altogether unneeessary, as nothing of the kind affects us in so deep water.

25. We find at present we ean cover a reservoir at about 1,000*l.* an aere.—It would be an immense work that would require a distributing-tank and filters to oceupy even two acres of land—this would be sufficient for London.

26. Would not that have the effect not only of preventing the water spoiling, but of preventing evaporation?—It is a great mistake to imagine that evaporation takes place to any extent, even in the height of summer, from the surfaee of a reservoir where the water is of any eonsiderable depth. The deposit of dew, I think, counterbalances it. I have one pond 10 feet deep, on whieh I made the experiment, and found in the heat of summer that in two months it did not go down one-

sixteenth part of an inch; and there might have been a small escape to account for even that diminution. Mr. Stirrat.

27. Do you line the sides of the reservoirs?—No; that is not at all necessary. We only line the inside of artificial embankments with rough broken stones.

28. It is the result of much experience in England, where water is derived from rock of the primitive formation, that, after coming through a channel of clay, it is of 10 or 12 degrees of hardness. It has been found in the instance of the Surrey canal that the hardness of the water rises in a curve?—I have found almost uniformly, that where rivers have a long *slow* run, it becomes harder the farther from its source. Thousands of contributing springs will no doubt produce this effect, by bringing mineral and saline matter into the main stream.

29. On the whole it is in accordance with the experience of the General Board of Health, who have received and have investigated some two or three hundred specimens of waters, that, on an average, well and spring waters are of 20 degrees of hardness; river waters, 13; and surface drainage water, about 5 degrees of hardness?—I have no doubt that that is an accurate calculation as a general average.

30. Have you been among or known populations, who, after having been used to soft water for drinking have had to come to the use of hard, or the converse?—At Paisley, they used to have water from spring-wells for drinking, but these springs contained iron, lime, and magnesia, although very pure to look at; and the population never complained of their use for anything but washing, for which they were not suited.

About 30 years ago, water began to be carted along the streets and sold to the people. This water was pumped up from the river and filtered, and was much softer than the springs, and did very well for washing and infusing tea, &c.; but since the introduction of soft surface water by the Company, the wells are not used for any purpose whatever, being totally neglected; and for drinking, the water of the Company is universally preferred, and relished most of any. I may here mention that the quantity now consumed for domestic use is so great, that had the people used the same quantity at the price charged from the barrels above-mentioned; it would have cost upwards of 100,000*l.* annually, and for which they now pay under 3,000*l.* annually.

31. Do you know that well-water derives its attractiveness from its coolness and freshness?—No doubt it does; averaging in summer from 45 to 55 degrees of heat; but our water from the main pipes is also quite as cool and clear, being under constant pressure in the pipes, and no cisterns in the houses where it would become heated and be thereby rendered unpleasant to drink.

32. But it has been objected to, and particularly by Mr. Thom, that water-pipes have been laid too near the surface?—Mr. Thom is quite correct in this remark; but, at Paisley and the Glasgow New Works, the pipes are laid 3 feet from the surface, and the water is found to be at all seasons quite cool enough.

In London, Manchester, &c., where water is taken into cisterns, in warm weather it uniformly becomes tepid and unpleasant to drink. In Liverpool, the water is very hard. I could wash at home without soap as well as at Liverpool with soap. I have stated that we are supplied at Paisley on the constant service principle, and the pressure (120 feet)

Mr. Stirrat. has never been off since 1838, when the supply began—except for part of a street, when occasionally the joint of a pipe was leaky and required repair, which operation is very easily and quickly done.

As to the effect on health in drinking and cooking with hard water, as compared with soft or rain water, it is a fact worthy of attention, that in Paisley, before soft water was introduced, cases of stone in the bladder were very frequent; and the late Dr. Stewart, an old and experienced practitioner, informed me that he had at one time known as many as a hundred cases in a year where an operation was necessary to extract stone from the bladder, besides many minor cases, where small stones were passed without operation; these cases somewhat diminished in number on the introduction of river water being sold from barrels; but that on the supply by the Water Company of pure soft water, such cases diminished year after year, and that for the last seven years there has not been a single case known to any of the faculty, unless where it had been generated in some other part of the country, and imported into the town. I find also, from inquiries made, that in Aberdeen, where the water flows wholly from granite, that the disease is unknown; the same is the result in the high parts of Derbyshire in England. On the other hand, in the county of Norfolk, where spring-water is used highly impregnated with mineral and saline substances, this disease exists in almost every family, more or less. I mentioned these facts to James Paton, M.D., of Paisley, and although he had not taken notice of the circumstance previously, he says it is quite correct; and that also diseases of the kidneys and liver, generated from the same cause, have wholly disappeared in Paisley.

33. From Bolton, we are informed that, since the introduction of soft water, the cases have diminished enormously. On the other hand it is stated that this result is rather owing to a diminution in the quantity of beer and other such beverages that are drunk?—The late Dr. Stewart, of Paisley, did not take that view of the subject; but he told me that for upwards of 20 years previous to the soft water supply to the town, he had not allowed the use of hard water in *his* family, they using the rain-water collected into a tank from the house-roof. The same effects may be observed in kettles and boilers in the quantity of fur where hard water is used.

34. During periods of epidemic disease, have you observed the different results of hard and soft water?—In Paisley, in 1832, every district of the town was affected with cholera, at which time there was no supply of water; but in 1848–49, in a high district, (Charleston,) with about 4,000 inhabitants, having no supply of water but spring-wells, the number of deaths were between 200 and 300; and in all the rest of the town, where the water supply was taken, the whole number of cases, I think, were under 50, and the deaths under 20.

In the Gorbals side of the city of Glasgow at the same time, the attacks of cholera were trifling, and the deaths very few; but on the north side of the Clyde, where the Clyde water is used, the cases were 4 to 500, about the half of which died. In 1832, the south side suffered most severely, and at that time they also used Clyde water. I cannot say positively, that all this was in consequence of using soft water; but such facts are worth attention.

35. Then, on the whole, the preponderance of experience goes to

support the greater salubrity of soft water over hard?—There is no doubt of that. Mr. Stirrat.

36. What is your experience as to the effect of soft water in cooking, tea-making, and washing?—Since we have used soft water, there is no comparison as to its value. For infusing tea, the flavour is good with a much less quantity; and in cooking, we of course get rid of all those deleterious substances, which, in an imperceptible manner, generate diseases; and as to washing and bleaching, any industrious housewife can tell the advantage. I should say, from experience as a bleacher, that if I were compelled to use the London or the Liverpool waters in my trade, that for every 1,000 lbs. of soap I use, I should have to use at least 2,000 lbs., and, after all, the same cleansing effect would not be gained.

37. What is your opinion, from your experience, as to the constant service supply, and the intermittent supply. Viewing it in relation to the modes in which the towns in England and Scotland are at this time supplied with water, and as to the expense, advantages, and disadvantages of the one mode as compared with the other?—I am most decidedly in favour of the constant supply system, whether I look to the interest of the Water Company or to the consumer.

There is less waste of water, the consumer never taking more than he wants at the time. The pipes of the Company are not corroded, the action of the atmosphere on the pipes in a damp state when empty being the cause of corrosion. Pipes under constant pressure will last three times longer than on the intermittent supply principle. The population have the use of the water at all hours, night and day. They have it at all times clear and cool.

In cases of fire it is almost impossible to calculate its value.

In Paisley we have fire-plugs on the mains, and also at Glasgow New Works; in the latter place there is a pressure of 220 feet, and by attaching a hose to a fire plug, which is the work of only a few minutes, any fire is immediately extinguished. It is scarcely possible to burn a house, the flow of water is so great and continuous, without any manual labour, that an ordinary floor of a house can be filled with water in 10 minutes. I do not mean to say that fire-engines should be dispensed with, as it is evident circumstances will occur where they may be of much use; but I say that in nine cases out of ten, if fire-plugs are placed at convenient distances on the mains, fire-engines will very seldom be needed. The New Glasgow Water-Works are the most complete and perfect in the kingdom, being self-acting throughout, by the self-acting sluices, invented by James Macinlay, who constructed the Shaw's Water Works at Greenock. Thus, supposing a great fire to take place in Glasgow (south side of Clyde), and four or five times the quantity of water were required that is usually given off, the moment such extra quantity is drawn off from the main pipe, these sluices act from the city on the reservoir, (five miles distant) and the same quantity as is drawn off the main pipe in the city, is discharged from the reservoir into the distributing-tank, and this discharge will continue for any length of time required, without the aid of any one, or any manual labour whatever.

This apparatus, however, would require to be seen and examined on the spot to be duly appreciated. The water here flows 40 feet (out of

Mr. Stirrat. the hose) above the highest house in the district, and when water is thrown on a house with *great force*, it is separated into millions of particles, and an immense amount of steam produced, which soon extinguishes a fire.

38. If a fire takes place in London, the average time before adequate aid is procured is above 30 minutes?—The time must vary according to circumstances; but with the fire-plugs and hose attached, the time generally will only be about one-fourth of that by fire-engines.

39. Have you not got into the habit of washing the streets by jet?—Not yet. I wished, as a member of the Town Council, that it should acquire the water-works to be under the control of the Corporation, in order to have that and other sanitary measures adopted; but so far we have not agreed on the terms. For many reasons, I am decidedly of opinion that Corporations alone should possess the right of supplying a population with water, and not a trading Company.

In the Gorbals of Glasgow, water is given gratis to all persons on the pauper-roll, and also to public bath and washing houses, if such should ever be erected.

40. What are your prices of a constant supply of water to small tenements?—In Paisley, there is a population of upwards of 40,000 supplied with water, the total population being 50,000, yet the whole rental of the burgh is only 50,000*l.*, including factories, &c.; the lowest charge there is 5*s.*: but, in the Gorbals of Glasgow, the charge is only 1*s.* per pound on all rentals; of course an apartment, rent 2*l.*, is only 2*s.* I may here state, that a charge on rental is not a fair data to rule by as to water-rates, that is, as to the price of any given quantity supplied. A house in Paisley may be had for 100*l.* a-year, that at Charing Cross in London would be rented at 300*l.*, and the *quantity* of water consumed in both houses be about the same.

41. Do you find convenience and improvement as a landlord from the more plentiful distribution of water?—I certainly do. The houses are much cleaner and in better condition in all respects. I have the charge of tenements, my own, and in trust for deceased friends, containing about 250 tenants, and I cannot let a house to any good tenant, even of the lowest labouring class, if water is not laid on in it. The poorest person will not take a house without water-pipes in it, if he can procure one with; and they uniformly prefer a house with the water INSIDE.

42. What is the quantity of water consumed by each person in your town?—The quantity given off now from the reservoir amounts to 45 gallons daily to each head of the population, but fully 25 gallons of this is used for manufacturing purposes, leaving nearly 20 gallons a-day for private use. I am aware that this is considered a large quantity, as compared with some other towns, but it is easily accounted for.

As an instance, in London the clothes are given out to the country to wash, but in Paisley nine-tenths of the population are of the working class, who wash all their clothes in their own kitchens, and having no water-closets, the quantity of water used where they have it so conveniently is much larger in washing their pots, than if they had a water-closet to resort to.

43. In Scotland, are the towns supplied generally on the constant

service principle, or by an intermittent supply?—By the constant service, in almost every instance. Mr. Stirrat.

44. Can you enumerate the places supplied by constant service?—Glasgow New Works, Paisley, Aberdeen, Dundee, Ayr, Kilmarnock, Pollockshaws, Govan, Troon, Ardrossan, Perth, Montrose, Greenock, Crossmyloof, Strathbungo, and many others; and Bills are now in Parliament to supply other towns on the same principle, viz., Nitshill, Hurlet, Barrhead, Neilston, Rutherglen, Dumfries, &c., &c.

45. What is the size of the main at Paisley, and the New Works at Glasgow?—At Paisley, 19 inches, with a pressure of 120 feet; and at Glasgow, 2 feet, with a pressure of 220 feet.

46. In London, it is estimated that the expense of washing is 1*s.* a-head per week, making the annual expense of washing in the metropolis not less than 5,000,000*l.* a-year; how much do you think a supply of soft water would save in soap in a year?—I should say, from my experience as a bleacher, that if we had to use water like yours in London, we should have to use at least twice the quantity of soap that we now consume.

47. What is the size of the service-pipes used by you?—In Paisley, half and three-quarter inch; in Glasgow, half-inch, in almost every case of domestic supply; and in Stirling, only quarter-inch lead pipes; the pressure in the latter place being 450 feet, these small pipes are found to be quite large enough.

48. Have you ever used clay pipes?—Such pipes were tried at Greenock, but were not found to answer; they gave way at the joints, and the jointing of them was found expensive and unsatisfactory.

49. Are there any other pipes than lead and iron that may be used, combining cheapness, and adding purity to the water?—Iron and lead are the only pipes that we have found to answer. Since I came to London at this time, I have been making inquiries as to glass pipes, and am offered, by Mr. Lochhead, the seat 1½*d.* per lb., to stand a pressure of 400 feet, and to be jointed with melted glass, by means of the blow-pipe, with solid glass. I have ordered a few, to make the experiment, but cannot say how it may do until a trial is made. Clay pipes were used in ancient times to supply water; as an instance, King Hezekiah (see 2nd Book of Kings, chap. 20, verse 20, and 2nd Book of Chronicles, chap. 32, verse 30,) brought in water from Jerusalem; his pool and conduit are still to be seen; the conduit is 3 feet square inside, built of freestone, strongly cemented; the stone 15 inches thick, evidently intended to sustain a considerable pressure of water, and I have seen pipes of clay taken by a friend from a house in the ruins of the ancient city, of one-inch bore, and about seven inches in diameter, proving evidently to my mind that ancient Jerusalem was supplied with water on the principle of gravitation. The pools, or reservoirs, are also at this day in tolerably good order, one of them still filled with water. The other, broken down in the centre, no doubt by some besieging enemy, to cut off the supply to the city.

50. What is the proportionate amount of storage necessary?—We find that in order to store up all the floods, so that no water may be lost, that we must have storage-room provided for two-thirds of the available quantity, that is, at Paisley, for 24 inches in depth from the extent of drainage. This storage is sufficient to store up the surplus

Mr. Stirrat. of wet years to make up for the deficiency of dry years on an average of 16 years' experience of the rain-fall, &c.

51. Then, on the whole, you find, that the constant supply at Paisley, and other places, constitute an immense and efficient preservation against fire?—No doubt of it. Many fires occur, but when the alarm is given, they are generally quite out in half an hour afterwards.

52. Have you heard at Paisley of pipes freezing?—The main-pipes never freeze, but sometimes the service-pipes do, where they are improperly placed.

53. What is the softest water you know to be supplied to any town?—The towns which have the softest water supplied are Paisley, Glasgow (New Works), Aberdeen, Dundee, Montrose, Ayr, Greenock, Kilmarnock, Troon, Ardrossan, &c. There is not much difference in any of these. There is no chalk nor lime in any of these waters, being all collected from hills of the primitive formations.

54. Have you found any inconvenience from the constant pressure in repairing pipes or mains?—Not at all; we have sometimes had occasion to deprive a street of water for a few hours, to repair a joint of a pipe, but that occurs very seldom indeed; not a dozen of places require such repair in twelve months in our population of 50,000.

55. In London it is said that soft water causes corrosion in pipes, and is liable to poison the population?—There is no such effect; such an idea is downright nonsense; corrosion in pipes takes place only under the intermittent supply, by the action of the atmosphere on the pipe in a damp state; and, as I have said before, an iron pipe constantly charged will not corrode at all, whether the water be hard or soft, and will last at least three times as long as a pipe into which the air is admitted.

56. What kind of pipes do you prefer—earthenware?—I should certainly say glass, if the cost and jointing could be properly managed, which, I am of opinion, will soon be done. Earthenware is unexceptionable, if it can be had to stand the pressure, and at a cost as cheap as iron. Lead pipes do give a taste unpleasant to the water, if not constantly being drawn off.

57. In London, not only the common air gets into the pipes, but the real gas gets in also?—No doubt of it. This must be the case, when the pipes are emptied of water; but on the constant pressure, nothing of the kind can by any possibility occur.

58. It has been alleged that if the supply of water were constant, that it would require an interference on the part of Water Companies that would be objectionable and unpleasant to consumers?—Experience shows that where water has been taken INSIDE of houses that it is well taken care of; whereas wells supplied by the Company at the backs of houses, open as they often are to a dozen of tenants, no care at all is taken of, on the principle that what's every body's business is nobody's; but when inside of a house every one takes care of his own, and there is no inducement to use more water than what is absolutely necessary. This almost entirely saves interference on the part of the Company.

59. Can you give the prime cost of bringing in water to the towns you mention, the population of the towns, and the annual expense of conducting the works, &c.?—Yes: at Paisley the cost

was 61,000*l.* Sixty-one thousand pounds, and I could have done it for 35,000*l.*, with the assistance of James Mackinlay, whom I have mentioned; but a very great extra expense was incurred from Mr. Thom's mistakes; but he being what was styled an EMINENT ENGINEER, his advice was followed at a great loss to the Company. Notwithstanding these drawbacks, we pay a 5 per cent. dividend annually, and for 10,000*l.* we could double the supply of water. Mr. Stirrat.

60. At the Gorbals Water Works, in Glasgow, can you state what the entire cost amounts to?—I can. The estimate by Mr. Gale, Civil Engineer, was 97,000*l.* and to complete the works 110,000*l.* were expended, but considerable additions have been made to the works involving fully 10,000*l.* of extra expense; so that the first estimate is beyond the sum that would have been required to finish the works as at first contemplated. This 110,000*l.* gives an ample supply to a population of 150,000, and a Bill is now in Parliament to increase these works; whereby, by an outlay of other 25,000*l.*, an ample supply can be obtained to a population of 250,000 allowing 20 gallons daily to each head of the population.

61. Then, you bring the cost of the main apparatus down to how much per head of the population?—The Gorbals Water Works would be at the outset about 16*s.* per head. The New Works contemplated will reduce it to about 10*s.* per head of an outlay, and to include the service-pipes to every family *inside* of the house, it will not exceed (12*s.*) twelve shillings per head.

62. What is the effect of the constant supply as to the quantity of water used?—There is less used unquestionably under the constant supply than by the intermittent supply, and, as I before said, it is the best system for the Companies, and also for consumers, in every respect.

63. What is the annual cost of management at Paisley and Glasgow New Works?—At Paisley under 600*l.*, and at Glasgow under 900*l.*, including all charges, cleaning filters, mending fences, &c.; and the annual expense will not increase with the extension of the works.

64. Then are you of opinion that a Water Company should not only lay the main pipes, but also the service pipes to each house?—I am most decidedly of that opinion, both for convenience to the consumers of water, and for economy and efficiency. The want of this power is the only deficiency in the Scotch Water Companies to which I have referred.

COPY of a LETTER from MR. GALE.

SIR, *Glasgow, 22nd April* 1850.

In reply to your letter ($\frac{10}{53}$), dated 16th instant, regarding the Inquiries which the General Board of Health are now instituting on the subject of a supply of water to towns, I now beg to offer the following remarks:—And, 1st. As to the source to be recommended, for giving a pure and abundant supply to a town; I would, generally, give a decided preference to the mode of collecting the water in reservoirs, from streams and surface drainage, where this is practicable, and can be accomplished at a reasonable outlay. Mr. Gale.

The plan which I usually adopt, is to fix upon a stream or streams,

Mr. Gale. on sufficiently elevated grounds, so as to admit of the water being introduced by gravitation.

In determining the position for the reservoirs, I keep in view the propriety of arranging them, so as to admit of extension from time to time, as the demand might increase, by the construction of additional reservoirs, on ground still more elevated, either in the same or the adjoining vallies, whereby the additional supply could be drawn into the lower reservoirs, and from thence into the filters.

This is a matter of essential importance where towns are rapidly increasing in population.

Water thus collected is generally found to be almost entirely free from matter held in solution, and that held in suspension is allowed to settle down to a great extent in the reservoirs and is drawn off to the filter beds in a comparatively pure state. It is also generally found to be remarkably soft, superior as a beverage, when properly filtered, to hard water, well adapted for brewing, making tea, washing, and culinary operations; or in other words, it is greatly to be preferred to hard water, for all domestic and manufacturing purposes whatever. The hardness of water thus collected I have found ranges from about 4 to 7 degrees, depending to some extent on the quantity and quality of the spring water, which must of necessity mingle with the soft when collected in the reservoirs.

There is also a better opportunity by this mode of getting water unpolluted by public works, and the refuse and sewerage of towns, which flows directly or derivatively into most large rivers, and which may be preserved from contamination by Legislative enactment.

Further, it is almost invariably found, that hard water is impregnated, to a greater or less extent, with carbonate of lime, and other deleterious substances held in solution, the constant use of which has a tendency to produce gravel and stone in the human system. In proof of which it may be stated that the inhabitants of the town of Paisley were much afflicted with these diseases previous to the introduction of pure soft water into that town, whereas now they have almost entirely disappeared; and again, the inhabitants of the town of Kilmarnock are, up to this moment, similarly afflicted, arising from the almost exclusive use of hard spring water.

In this latter case I anticipate a remedy in the course of a few months, by the introduction of a plentiful supply of soft, pure filtered water.

Again, during the late attack of cholera, both in Paisley and Gorbals, the cases were comparatively rare, with the exception of that portion of Paisley beyond the range of the Water Company's pipes, where the cases were numerous; and in the same town, in the first attack of that disease, before the water was introduced, it was very severely felt. The town at that time, was supplied partly from springs, partly from roof water collected in tanks, and partly by carrying it from the River Cart, and doling it out to the inhabitants in pitcher fulls, in the same way as is done in the town of Dumfries at the present time.

The south side of the city of Glasgow, including the town of Pollokshaws, with other villages along the line of mains, comprehending a population of about 75,000, is supplied from a stream, draining 2,750 acres, distant from Glasgow about 7 or 8 miles, which stream,

Mr. Gale.

by the formation of another reservoir, immediately above those already executed, (a Bill for which is now before Parliament) will then yield an abundant supply of water of the finest description to a population of about 250,000.

The town of Paisley, containing about 60,000 inhabitants is amply supplied from a drainage of about 700 acres, besides giving compensation to the mills.

Stirling with a population of 10,000 is supplied from a drainage of about 150 acres; the contributing ground in this case being chiefly whinstone and hilly pasture; filtration was found to be unnecessary on account of the purity of the water collected in the reservoirs. The contributing grounds to Gorbals and Paisley were pasture and arable land, and in both cases the water is filtered.

In the towns above enumerated, the water is giving entire satisfaction to the inhabitants, and the Towns of Kilmarnock, Stranraer, Dumfries, and Maybole, are following out the same system of supply, which I have no doubt will give equal satisfaction when introduced,

There are many objections to the system of pumping water from large rivers, for the supply of towns. In the first place, it is found that they are generally liable to become polluted by public works and from the drainage of towns and villages, an evil which is gradually increasing; this is felt mostly during long droughts, when the waters are in a low condition; as an example, the Glasgow Water Company draw their supply from the River Clyde, about two miles above the city, above which point there have been numerous public works and populous towns and villages sprung up on the river and its tributaries. This growing evil compelled the Company to apply for power to have it remedied, by drawing their supply from a source, upwards of 30 miles distant from the city; the power was granted, but the works have not yet been carried into execution.

Further, in drawing from rivers the water would necessarily be drawn at times, when it was in a turbid state, tending more readily to choke up the filters; and again, when water is abstracted from a river, compensation in money would have to be paid to parties interested, in many cases, as no compensation in water could possibly be given. Whereas, by storing up the surface-water, as has been proposed, in reservoirs on elevated grounds, compensation in water may be given out regularly during the whole year, generally to the extent of one-fourth of the whole available fall of rain; whereby the mills and public works are infinitely better supplied than they are, when obliged to take the water when it comes, at one time having a great deal too much, and at another a great deal too little.

Another advantage a gravitation scheme has over a pumping scheme is, the comparatively small annual expense required for the former, where the works are properly constructed. In the case of the Gorbals gravitation Water Works, one superintendent, with the occasional assistance of two or three labourers, when cleansing the filters, is found to be quite adequate to send a constant supply of pure water into the town; and were the population trebled, the additional expense in cleaning the filter beds would be but trifling.

As to the mode of supply from wells or deep springs, I am of opinion that it should never be resorted to, if it be possible to get a supply of

Mr. Gale.

pure soft water, even although the original cost of constructing the latter should exceed that of the former to a considerable extent, and that for the reasons already stated, with regard to its quality and the constant expense of pumping. Further, casualties are by no means of rare occurrence, which affect to a great extent both the quantity and quality of the water of springs, and, therefore, I could not recommend that mode of supplying a town with pure wholesome water.

As to the adoption of a constant supply in preference to an intermittent one I think there can be but one opinion, and I feel satisfied that no one having had the experience of the former would ever think of falling back on the latter. The reasons are obvions. First, it is less expensive in the annual outlay, fewer hands being required. Second, the water is less disturbed in the pipes, and is introduced into the houses in a fresher state than if allowed to stagnate in the pipes and cisterns. Third, there is no necessity for the tenements being supplied with tanks or cisterns. And, lastly, in the event of fires, the water being constantly at hand, the plugs may be opened without delay. And where the source of supply is sufficiently elevated, the aid of fire-engines may be altogether dispensed with, as in the case of Gorbals where there is a head pressure of 225 feet; Stirling with a pressure of 450 feet, and Kilmarnock with a head of 270 feet.

The pipes in all cases are constantly charged, and by the adoption of the improved fire-plug, and connecting stand pipe four hose may be made to play from each fire-plug with better effect than with as many engines.

Fires have occurred in Gorbals where they have been got under and extinguished before the arrival of the engines and their attendant butts. This is a matter of great importance in all large towns where so much property is annually destroyed by the ravages of fire.

In concluding this part of my remarks I would merely state, that if possible, where any new Water-works are to be established the system of constant service should be adopted; and in cases where the intermittent system is already in existence, that the advantages of a change to constant service would more than counterbalance the expense of making the necessary alterations.

As to "the average daily domestic consumption, as distinguished from the quantities used in manufactories, or by other large consumers, and that used at standpipes, and in watering roads and streets, and other public purposes," there is some difficulty in arriving at definite conclusions in detail, on account of the want of proper meters for the public works, this defect I expect soon to overcome, when I shall institute some experiments so as to get proper data upon which to proceed. The results, when obtained, I shall be glad to transmit to the Metropolitan Sanitary Commission.

In the meantime, I may observe, that from observations made on the total consumption in Gorbals, for all purposes, it averages about 32 gallons to each individual, daily; and that for a town such as Glasgow nothing less should be calculated on where so many of the houses are fitted up with baths and water-closets, and where manufactories and other public works are so numerous.

In towns such as Kilmarnock, Stirling, &c., where the luxury of a bath is rarely met with, except in the higher class of houses, and

where public works are not so numerous in proportion, 25 gallons daily, and for small towns 20 gallons should suffice. Mr. Gale.

I am aware that in some small towns the inhabitants would not use more than one-half that quantity; but in a sanitary point of view, I am of opinion that nothing less than 20 gallons daily to each individual should be calculated upon for all purposes.

I beg further to annex analysis of the water supplied by the Gorbals Gravitation Water Company:—

	Grs. in imp. gall.
Organic matter	1·150
Carbonate of lime	3·610
Sulphate of lime	·870
Common salt	·881
Sulphates of potash and soda	·299
Magnesia	·120
Oxide of iron	·070
Silica	·150
Total quantity of foreign matter	7·150
Specific gravity	1·000·159
Degrees of hardness according to Dr. Clark's scale and process	4·25°

The above analysis was made on the 27th June 1845 from specimens taken from the running stream, and no analysis has been made since the works have been completed; but I believe that, from the subsidence in the reservoirs and the filtration which the water afterwards undergoes, that the water will not only have been deprived of all organic matter held in suspension, but also that the amount of other foreign matters held in solution will have been to some extent reduced, rendering it nearly equal to rain water, seeing that the specimens were taken in dry summer weather.

As to the evidence of Mr. Martin, of Wolverhampton, and the statement of Mr. Coulthart, of Ashton, I entirely coincide with them in the advantages to be derived from a change from intermittent to constant supply.

I do not, however, think that this change should require the laying down of larger mains as stated by Mr. Coulthart.

I am a little surprised that so little water is used for domestic purposes both at Ashton and Wolverhampton, but I have no doubt that the statements made regarding the supply of these towns are quite correct.

There is a difference of opinion regarding the propriety of reticulating the street pipes throughout a town, but this is a point which is probably unnecessary to examine in these remarks.

I beg to send annexed to these remarks a few tracings explanatory of portions of some of the works in which I have been engaged, and which may probably be of some use in drawing up the Report of the Metropolitan Sanitary Commission.

Drawing No. 1 exhibits a plan of the reservoirs, and other works connected therewith, belonging to the Gorbals Gravitation Water Company, which have been in operation for upwards of two years; also of

Mr. Gale. — the proposed reservoir immediately above those already constructed, to which reference has previously been made; which reservoir, including those already constructed will contain 962,500,000 gallons. The lower reservoir is filled up from the upper ones so soon as the water has been allowed to settle; thus keeping the water in that reservoir which supplies the filters in a comparatively pure state.

Drawing No. 2 exhibits the lower reservoir in connection with the self-acting sluices, filters, and pure water basins. By means of the self-acting apparatus which has been adopted, the pure water basins are kept at the same level, whether the draft at the town be great or small, by first operating on the conduit leading to the filters, and then upon the valve on the pipe leading through the embankment to the lower reservoir—thus making the whole works self-acting, without the intervention of manual labour.

Drawing No. 3 shows, on an enlarged scale a plan of the filter beds and pure water basins. It will be seen that there are three filtering beds and basin in duplicate, either set of which can be worked while the others are being cleansed: the water, upon leaving the conduit, passes through the upper filter, rises up in the hollow-wall, separating the centre from the upper filter, falls on to the second filtering bed, passes through the filtering material of sand and gravel, rises in the second hollow wall, thence through the material of the third filter, composed of sand, again rises in the hollow wall, separating the lower filter from the pure water basin, and at length into said basin, by which means, the whole water undergoes a triple filtration. The water is conveyed from the pure water basin into the town by a 2-feet main, and distributed by constant service in the usual way.

Drawing No. 4 exhibits the various heights of the reservoirs and pure water basins above the Broomielaw Quays at Glasgow.

Drawing No. 5 shows a section of a similar arrangement to the Gorbals Water-works now executed for the town of Kilmarnock, but upon a much cheaper and simpler plan; the whole of which, as in the Gorbals Works, is self-acting throughout.

Drawing No. 6 shows how, in a small town such as Stranraer, where the water is collected in the reservoir in a comparatively pure state, may be sent into the town without filtration by means of a moveable pipe and float, surrounded with fine wire gauge screens which retains matter held in suspension, and from the simplicity of the arrangement, can be taken out and cleansed when found necessary.

One of the great objects I have invariably found in supplying small towns is an economical mode of constructing the works, otherwise the projects would, in many cases, have been abandoned.

In concluding these remarks, I would beg to state that I shall be happy, if required, to furnish any additional information in my power, as well as give such facts bearing upon the subject which may be elicited from time to time in the prosecution of, or experimenting upon, a branch of engineering so deeply affecting the well-being of society wherever congregated in masses.

I have the honour to be, Sir,

Your most obedient Servant,

(Signed) William Gale.

Henry Austin, Esq.

Mr. Braithwaite.

Frederick Braithwaite, Esq., M. Inst. C.E., examined.

How long has your attention been directed to the supply of water from wells?—Since 1835, when I succeeded my brother, John Braithwaite, I have been professionally engaged in obtaining supplies of water from wells. My father and grandfather, as also my brother, were for many years similarly engaged. The men employed were Doxey, sen., Doxey, jun., Powell, sen. (all dead), and W. Powell, jun., now residing at Hornsey-lane, Islington.

Chiefly in the metropolis, I believe?—Yes; and some distance round London, 15 to 20 miles. I have personally superintended the sinking and formation of the principal wells in London.

Will you put in a chart of the principal deep wells in London?—I will do so.

Will you mention the wells that you and your house have constructed?—

The Blackwall Railway, Minories.
Reid and Co., Liquorpond-street.
Greenwich Hospital.
Combe and Co., Castle-street.
Meux and Co., Tottenham-court-road.
Hanbury and Co., Brick-lane.
Barclay and Co., Southwark.
Calvert and Co., Thames-street.
Charrington and Co., Mile End.
Goding and Broadwood, Broad-street.
Hampstead Water-works.
Conservative Club, St. James's.
Union Club, Pall-mall.
Ravenhill and Miller, Glasshouse-street.
Weiss, Strand.
Potts, Vinegar-yard, Southwark.
Russell and other squares.
Hodgson and Abbott, Bow.
Deany and Henley, }
Kingston Union, }
Robarts, Roehampton, } Superintended as altered.
Durant, Putney, }
Barnett. }
Bridgewater, Countess of.
Bricheno, Skinner-street.
Richmond, Ratcliffe.
And many other smaller wells at Cobham, Leatherhead, Hertfordshire, and other localities.

Have you any sections showing the different strata passed through in sinking wells in the metropolis?—Yes; and I have sent some for the inspection of the Honourable Commissioners. I would refer them to a particular set of samples of the different strata passed through in sinking the well at the Minories, which I had the honour of presenting to the Museum of Economic Geology.

At what depth did your borings commence, and to what depth were

Mr. Braithwaite.] they carried, in the several wells referred to?—At Messrs. Meux and Co.'s, Tottenham-court-road brewery, the well had been sunk into the chalk to a depth of 40 ft., yielding 30 gallons of water per minute; a boring to a further depth of 229 ft. only yielded 10 gallons per minute. Tunnelling was then adopted in the direction of the fissures in the chalk, when the total quantity of water obtained was 100 gallons per minute, since which the supply has fallen off, and the tunnelling has been twice extended, obtaining an increase of 1-5th. This well originally had an abundant supply of water from the sand-spring, *now dry*. This remark will apply to many wells in London. This well is dug to the chalk 156 ft., in the chalk 40 ft., and bored 229 ft.; total depth 425 ft.

Greenwich Hospital well was sunk to the chalk 123 ft. 6 in. from the surface, dug 30 ft. in the same, and then bored 100 ft.; in all 253 ft. 6 in. deep. The peculiarities of this well are, that there is only about 4 ft. of plastic clay, and no blue clay: that the land-spring is comparatively inexhaustible; it rises to within 14 ft. 6 in. of the surface, and ebbs and flows with the tide 2 ft. 6 in.; it extends to a depth of 35 ft. in Thames shingle or ballast. The sand-spring very abundant; but not more than 60 gallons of water per minute could be pumped *free of sand;* this spring rises to 11 ft. 9 in. from the surface, and ebbs and flows 3 ft. each tide. The chalk-spring was not so abundant, yielding only 120 gallons per minute at 58 ft. from the surface; ebbs and flows 4 ft. 6 in.

Professor Graham's Report.

"The water of the three wells is decidedly hard for deep wells in which the water comes from below the deep clays; being harder by one-half at least than Thames water, &c. &c.

"Several of the deep wells about London which I have had the opportunity of examining are softer than Thames water; and the only reason I can give for it is their greater depth than the Greenwich wells.

(Signed) "THOMAS GRAHAM."

I hand in an analysis of three waters taken from bored wells to the chalk at Greenwich and Deptford, made by Professor Graham at the same time.

Page's Brewery, Greenwich.
In 1 gallon 70,000 grains.

	Grains.
Carbonate of lime	21·23
Sulphate of magnesia	2·88
Sulphate of soda	0·60
Chloride of sodium	3·12
Solid matter	27·83

Lambert's Brewery, Deptford.
In 1 gallon 70,000 grains.

	Grains.
Carbonate of lime	16·74
Carbonate of magnesia	0·80
Sulphate of magnesia	2·75
Sulphate of soda	2·67
Chloride of sodium	1·91
Loss	1·33
Solid matter	26·20

Page's Well.

Feet.	
124	to the chalk.
152	bored in ditto.
276	total depth.

Lambert's Well.

Feet.	
55	to the chalk.
123	in chalk bored.
178	total depth.

Mr. Braithwaite.

Greenwich Hospital.
(1 gallon 70,000 grains.)

	Grains.
Carbonate of lime	19·08
Carbonate of iron	0·52
Sulphate of magnesia	2·04
Sulphate of soda	3·62
Chloride of sodium	0·37
Loss	1.67
Solid matter	27·30 in one imperial gallon.

N.B. Iron cylinders were used throughout.

Reid's well.—Cylinders carried down and into the chalk, which is 135 ft. from the surface; excavations in the chalk continued to a depth of 178 ft. from the surface, increasing the diameter of chalk well to 16 ft. 6 in., when it was continued at those dimensions to a further depth of 24 ft. (202 ft.) Up to this point only 50 gallons per minute of water was obtained. At 196 ft. a tunnel 7 ft. by 6 was driven 96 ft. A second was driven 120 ft., 6 ft. by 4, producing a further increase of 10 gallons per minute from No. 1 tunnel, and of 37 gallons per minute from No. 2 tunnel. A boring was then made 20 ft. deeper, which yielding an increase of 7 gallons per minute, a 7-ft. shaft was carried down, and two more tunnels, one 96 ft., and the other 24 ft. 6 in., in the direction of the fissures, giving an increase of 116 gallons per minute; producing in all not 200 gallons per minute. Cost 7000*l.* Superficial feet of chalk exposed in this well, about 1600 ft. N.B. Of this well it may be remarked, that, like many others, there was originally a large quantity of water in the sand-spring; in fact, nearly as much sand as water was injuriously raised. The house, before the sinking of the above well (1841) had the supply from the New River Company, and, in consequence of the falling off of the supply in the new well, recourse has been again had to the Water Company. During the progress of sinking this well I tried experiments on the *absorbing* powers of the chalk taken immediately above and below the fissures. I send the table.

A Table showing the Weight of Water absorbed by a given Weight of Chalk taken from above and below the Fissures at different Depths.

At 27 ft. deep. Above the fissure a piece of chalk weighing 9 lbs. 15½ ozs., after 72 hours' drying, lost 10¼ ozs.

Below the fissure, weighing 10 lbs. 10 ozs., after 72 hours' drying, lost 16½ ozs.

At 53 ft. deep a piece weighing 3 lbs. 9 ozs., after 72 hours, lost 11 ozs.

Below the fissure a piece 4 lbs. 15 ozs., after 72 hours' drying, lost 1 lb. 1 oz.

At 68 ft. deep a piece above the fissure, 12 lbs. 3 ozs., after 72 hours, lost 2 lbs. 3 ozs.

A piece below fissure, 10 lbs. 9 ozs., after 72 hours, lost 1 lb. 15 ozs. Specific gravity of chalk 2781.

Messrs. Combe and Co.'s two wells at the brewery, Castle-street, Long-acre.—In consequence of the rapid decline of the water in the sand-

Mr. Braithwaite.

spring (173 ft. deep) in the new well, and the expense of obtaining water from the sand-spring in the old well, which, from pumping too much sand some years ago, had fallen in at the bottom, the house determined to bore to and into the chalk, which is 223 ft. from the surface. A boring was at first carried down 100 ft., the stated depth by certain authorities where the "great water-bearing stratum" was to be found, but with little or no success; the boring was continued to 300 ft. in the chalk, in all 523 ft. from the surface, still with a trifling supply of not more than 20 gallons per minute. N.B. The new well being provided with an accurate gauge enables me to furnish the Commissioners with the accompanying table of the decline of the water in the sand-spring from July 1837 to December 1849. The table has been compiled monthly:—

If the Commissioners should require it, I can with pleasure furnish them with many more details of borings in the several wells I have previously named.

How far do you think the deductions to be drawn from the facts which have occurred under your own observation, conform to the prevalent views of geologists or of the projectors of Artesian wells?—I am of opinion that the result of my observations warrants me in conforming to the views of Dr. Buckland and other geologists, who consider the water in the deep springs under London or of the London basin as exhaustible, and that, comparatively, in a very rapid degree. I therefore differ with the projectors of the Artesian wells, who are, in my opinion, led into error by the partial success of wells sunk in a deeper part of the assumed basin. I allude more particularly to the *three wells* sunk, one opposite the National Gallery, and two others in Orange-street. If I may be permitted to digress, I am of opinion the Commissioners should obtain *correct* information touching these wells. But I wish it to be distinctly understood that I admit that there is still a large quantity of water in certain localities both in the land and sand springs, but I entertain serious doubts if any large quantity of water is to be obtained from the chalk under the metropolis, for in several of the chalk-spring wells, although but *recently* sunk, the water is sensibly declining.

What has been the success of the Hampstead Water-works?—The first well was sunk by my brother on the hill by the side of one of the upper ponds to the sand-spring 336 feet deep. A 12-horse engine was erected, and for some considerable time there was a good supply, but the pumps were only worked in times of deficiency in the surface-waters. Since then, in consequence of the falling off of the water, Mr. Mylne was employed to sink another well to and into the chalk. I am informed that the well is dug 321 feet to the chalk, 255 feet in the chalk, with a very short supply, and that he is now boring for more water.

What are your recorded observations of the effect of the pumping and the deep working at one part of the metropolis upon another?—Several. The most remarkable instance is now in operation. The pumping at the wells near Trafalgar-square is drawing the water rapidly from Messrs. Combe and Co.'s well, the Union and Reform Clubs' wells, and others. That at Combe and Co.'s, before the sinking of the Trafalgar-square wells, produced the same effect upon Covent-garden well, for until the pumps were lowered in that well, which I had advised to be done in the first instance, the engineer was compelled to pump two or three hours

before Combe's pumps began work. There are several other recorded instances. The effect of Barclay's pumping on Calvert's well; in fact, there has been one universal depression in all the wells to the sand-spring, varying only in degree according to the various depths. I may mention two instances not exactly in the metropolis. The one occurred at the brewery of Messrs. Tritton at Wandsworth, where the well, drawing the supply from a neighbouring well (Mr. Rutter's), was the subject of a lawsuit. The other occurred at the Kingston union well, sunk to the sand-spring 425 feet, where the water rose to within 7 feet of the surface, which, when lowered by pumping to 25 feet, affected Mr. Palmer's well, which was about 200 yards distant, also sunk to the sand-spring. Mr. Palmer's well is situated something lower than that at the union, and was really *an Artesian well, for it overflowed;* but when the water at the union well was lowered, as above stated, it (Palmer's well) ceased to do so. This discovery led to the correction of an important error; it was always stated that Mr. Palmer's well-water was from the chalk, but it is only from the sand. Mr. Braithwaite

Are there many of the domestic wells remaining?—I think there are; but many of them have lost a considerable portion of their supply, arising from the construction of the deep sewers cutting into and through the first bed of gravel, in which the land-springs are or were found.

Will you state the nature of your proofs to show that the Thames water really does affect the well-springs?—The proofs I adduce are three: 1. The well at Greenwich Hospital, where, as I have previously stated, the land, sand, and chalk springs are *tidal.* 2. The fact that in 1832 the water in 10 of the principal wells in London rose to and stood at the level of Trinity high-water mark, but does not now rise to the same level within 50 and more feet. 3. The fact that the water of the *deep wells* is found, upon a recent analysis, to contain considerably more saline matter than heretofore. I hand in a table of the analysis of seventeen different waters; the red figures denote those of the deep wells under London.

It is stated that, in the course of digging some time since on the premises of the Vauxhall Water-works for the formation of a reservoir, an enormous supply of water was found, which was very clear, but possessing chalybeate qualities, and was totally distinct from the Thames water?—I am not aware of that fact.

Will you put in any illustration of the evidence of this tidal effect upon the wells?—I have done so; but ocular proof may be obtained at the well at the brewery of the Royal Hospital, Greenwich. It will be only necessary to ask the authorities to allow the pumping to be discontinued a few hours.

Were these waters analysed?—The chalk-water was analysed by Professor Graham, and I have given the analysis. The sand-water was also analysed, but I have not the analysis. I understood there was little difference between that and the water from the chalk. The land-water is very hard indeed.

It appears that the brewers, who can avoid it, never use the Thames water?—My opinion is that the preference shown to well water is on account of its temperature, varying, summer and winter, from 52° to

Mr. Braithwaite.

54° only; which enables the brewers (being able to refrigerate the worts) to brew all the year round, with a large economy in hops.

Then you think it is temperature, rather than quality, that the porter brewer requires in the water?—Confining the question to well and river water, I think it is: for I do not consider there is any material difference in the quality; it is true that the well-water is more filtered.

Will you put in an analysis of the Greenwich well?—I have done so.

It is said that the water of the well in Trafalgar-square is only 4 or 5 degrees of hardness, and that it is not more than one-third the hardness of the Thames water. Supposing that to be so, would not the different solvent powers of hard and soft water make a great difference in the respective value of such water?—I presume degrees of hardness refer to Dr. Clark's table, where each degree represents *one* grain of carbonate of lime in one imperial gallon of 70,000 grains; if so, then it would appear that there are from *four* to *five* grains of carbonate of lime in the well-water of Trafalgar-square, and 12 to 15 grains in the Thames water. If the carbonate of lime in the well-water of Trafalgar-square had been thrown down by Dr. Clark's process, then it would have been rendered comparatively the more valuable; but when, as is no doubt the fact, the carbonate of lime has only been replaced by a large admission of soda and other salts (namely 66 grains), I am justified in attaching the greater value to the river Thames water. For *washing* purposes the well-water may be preferred.

Of course, the sand-spring water is artificially filtered. Is not that an advantage on its side?—Clearly so.

What would be the expense of one or more of these larger deep wells?—

	Messrs. Reid's cost . . .	7,000*l.*
	Blackwall Railway . . .	8,000*l.*
Published	New River	12,400*l.*
	Hanbury's	5,795*l.*

It is difficult to state the cost of many of the deep wells in London; it may be said that many of them, more or less, have been a continued source of expense and trouble to the proprietors. The expense varies, for some of the wells have distinct engine-power, and some are worked by the engine of the establishment doing the general work.

Is the surface-water, as a general rule, softer or harder than the Thames water, whatever strata it may be obtained from?—If by this term surface-water I am to understand it to mean land-water, I would observe that I have, I may say, found it always harder than the Thames water; and that the land-water I have found has been in the yellow gravel above the blue clay.

Can you show the extent of influence of one well over others?—This question has been answered.

Have you had any observations as far as Watford?—None beyond reading the Reports and controversies of Messrs. Stephenson, Clutterbuck, Dickinson, and others.

Supposing an impermeable drainage to be substituted for a permeable brick drainage, must it not be accompanied with permeable

drainage for the places requiring it on account of the damp?—Certainly; but the lower portions of the sewers in loose or made ground should be impermeable. Mr. Braithwaite.

Mr. George Donaldson examined.

You are one of the assistant engineers of the Metropolitan Commission of Sewers, specially conversant with land-drainage works?—I am. Mr. Donaldson.

You were directed to make examinations for the sanitary improvement of Richmond, Sydenham, Croydon, Greenwich, and other districts near the metropolis, and in those examinations to include provision for improved water supplies for domestic use?—Yes, I was.

You have also been led by your avocations to make examinations as to the state of the surface soil and subsoil of large tracts near the metropolis, and the qualities of the waters with which they are charged?—Yes, I have done so all round the metropolis.

Within what distances?—Within 12 miles on the north, and from 25 to 30 miles on the south-east, south, and west.

To take one instance closely adjacent to the river Thames, that of Richmond; had you any instances there of drainage, or what may be more properly termed artificial spring water?—Yes; a large part of Richmond Park has been very efficiently drained, under the direction of Her Majesty's Commissioners of Woods and Forests; and from those works there arises a constant and copious supply of artificial spring water.

What is the nature of the soil?—It is a sandy or gravelly loam, incumbent in a clay subsoil.

What did you find to be the quality of the water derived from this surface?—It was perfectly clear; soft to the feeling, well aerated, and pleasant to drink.

Was it so clear as not to need filtration?—It was so clear, that I would not think of filtering it for drinking. It was more brisk than filtered water usually is.

What was the analysis?—There were several specimens from the tract of land drained. There was a large portion of water which had only three degrees of hardness. The average of six specimens was four degrees and one-third.

Would that have been the average of the bulk of all the water taken from the park?—I think the average of the bulk would have been about five degrees.

What at that point are you aware is the average degree of hardness of the Thames water which runs beneath Richmond?—I believe it is about 13 degrees.

That is to say, about three times as hard as the artificial spring water from the land close by?—Nearly so.

Had you any opportunity of comparing the surface water from the undrained portions with the shallow spring water derived from the portions drained?—Yes, several opportunities.

What were the characteristic differences?—The surface water generally holds in suspension earthy and other matters, taken up in passing over the surface.

Mr. Donaldson.

Did you get these surface waters analyzed?—No, I did not think it necessary for the purpose in hand. I am, from long observation, aware that water passing through a bed of vegetation does leave behind, not only the matter in mechanical suspension, but much of the matter in chemical solution. This is a point which has hitherto not received the attention which its importance deserves. I am quite sure that a bed of vegetation will detain for its food saline and other matter in solution, which no sand or other artificial filter will separate from the water. I have seen water, containing a considerable quantity of sewage from a farm-yard, which has passed upon well-drained pasture land, and the water which has drained through it has come out perfectly clear from the manure in solution.

Was it so clear that you would have drank it?—I have freely drank it. It had all the appearance, and tasted as perfectly pure spring water.

It is to be presumed, however, that there might be an extent of manuring or shallowness of the filter-bed of earth which would not detain the matter in solution?—No doubt of it. Wherever the drainage is shallow, and the quantity of manure excessive, no doubt some of it would be left in the water. In the case I referred to the drainage was from 3 feet to 4 feet in depth.

You were only understood as stating that filtration through a bed of earth would detain matter in solution which a common sand-filter or any other mechanical filter would not detain?—Clearly so; that is, when the surface of the land is covered with vegetation.

It accords with your observation, then, that shallow or artificial drainage water is of a superior quality and must generally be so, to ordinary surface water?—Decidedly so.

Does it also accord with your observation that it is superior to the common river water?—Greatly superior in purity to the common river water.

What is the extent of gathering ground for shallow spring water which the whole of the Richmond Park might afford when all drained?—The whole of the park is about 2,337 acres, of which nearly 2,000 acres might be made available as gathering ground.

What quantity of water might be derived from that 2,000 acres?—About 400 millions of gallons per annum.

What is the average rain-fall there?—I estimate the rain-fall at 25 inches, of which I think 10 inches may safely be calculated upon as the quantity which could be collected and stored.

Are there any local peculiarities to account for the deviations in the ordinary calculation of surface-water from rain fall, namely one-third the amount of the annual rain-fall? There are; the nature of the soil on the surface is such as to absorb water as it falls; also the nature of the subsoil which is such that very little will percolate so deep as to be lost.

Seeing the quantity of rain-fall which will be drained by the drainage of land, and the larger proportions obtained from gathering grounds than from the mere surface discharge of water, may not such gathering grounds be economically contrasted with the system of surface drains?—The effect of drainage is to make the ground more permeable and more absorptive, so that the water soaks into it more readily.

Mr. Donaldson.

Then the water will not be detained there?—It will not evaporate from the surface.

Then there will be not only less loss from the surface from evaporation, but also less loss of temperature?—Clearly so.

Of course drainage improves vegetation, which is due as well to the matter left by the rain as to the action by permeation of the air?—I believe it is so.

Have you observed an advantage in this shallow spring water in its freedom from animalculæ as compared with other water?—I never met with animalculæ in spring water as it came from the spring or drain.

Take the case of Richmond, what number of houses would such a gathering ground as Richmond Park supply at the rate of 50 gallons per house per diem?

Have you estimated the extra value to each house if it were supplied with water of this quality, viz., one-third the degree of hardness of Thames-water, would it not be an immense saving in soap?—No doubt of it; but more specific information on this subject, derived from actual experience, is desirable.

Would you think it necessary to use any filtering remedies for such water?—I think it would be unnecessary if the reservoir were suitably made. The natural filtration through which it has passed is in my view superior to any artificial mode.

Were you not called in to report on the sanitary condition of Sydenham?—I was.

Did you find any surface-water there?—Not much worth notice. The land there is mostly clay, and the surface-water was hard and rather brackish, so was the water from the wells, and charged with a clayey colour. It would not answer for household purposes; a little beyond Sydenham, some half mile from the town I found a supply of only two degrees of hardness. I did not gauge the quantity, but think it would be sufficient for all Sydenham.

Is Sydenham within the jurisdiction of any water company?—Yes, of the South Lambeth Water Company.

Supposing you laid down a distributory apparatus for Richmond, at what cost could it be done per house?—Four pounds per house.

What was your estimate of the price at which it could be done for Sydenham?—Five pounds per house.

At Richmond did you design to distribute the drainage at the backs of the houses?—In a great number of cases, and also the water-supply where it was practicable, as a saving of a great length of pipe. The supply being near to the wash-houses where it is wanted.

What do you find the saving from back drainage to be as compared with front drainage?—As a general rule, it is something like 20 feet of house-drain pipe per house, and a proportionate saving in the length of water-pipe.

In general does it not save two-thirds of the distributory apparatus?—Nearly so; and it makes the apparatus itself more compact, and less liable to injury.

What is your estimate of what the water-supply could be furnished to Richmond for, per house, from the supply in the park?—Seventeen

Mr. Donaldson.

shillings and sixpence per house per annum would repay the whole outlay with interest in 22 years, and cover the cost of working and superintendence.

Suppose the population had the choice of the Thames River water or this shallow spring water, what would it be worth while for the inhabitants to pay per acre, if they could be supplied with 100 gallons per diem as compared with the supply of the river?—As affecting health the difference between pure spring water and the Thames water is above all price; as a matter of economy in washing and for other domestic uses, it would be worth an annual payment of three guineas per acre assuming the water not to exceed five degrees in hardness.

From several analyses and calculations as to the saving in soap by the use of soft water; and from inquiries I have made of numerous consumers, of the quantity of soap used per individual, it appears that for every 100 gallons of water used in washing, two ounces of white curd soap is required for every degree of the hardness of the water used.

Thus a water of 5 degrees hardness takes . . 10 ounces of soap,
And one of 15 degrees hardness takes . . . 30 ,, ,,

I find that 14 lb. per individual per annum is about the average consumption of yellow soap for washing and domestic use, and the price is about 5*d.* per pound. Therefore 100 individuals using water at 15

	£	s.	d.
degrees hardness takes 1,400 lb. of soap at 5*d.* per lb. .	£29	3	4
And with water 5 degrees hard, 466 lbs.	9	14	3
Difference	£19	9	1

In round numbers the saving in soap by using water 5 degrees hard instead of 15 degrees is 20*l.* per 100 individuals, exclusive of the tear and wear of clothes from washing in hard water which will fully equal the saving in soap.

How many families at your estimate of the gathering grounds can be supplied per acre?—One inch deep of rain-fall on an acre will supply 10 cubic feet per day for a year, which I assume as a minimum quantity per house per diem. So the depth in inches of rainfall obtainable indicates the number of families it will supply during one year. The average rainfall being 21 inches, one-third of that would supply seven houses. Assuming the number of houses in the metropolis at 300,000, and assuming the rainfall per annum at 24 inches, one-third of that, = 8 inches, gives eight families per acre; at this rate it would take 37,500 acres, or 58 square miles of gathering ground. The irregularity of a rain supply necessitates large reservoirs, equal to three or four months supply. The cost of draining 37,500 acres, at an average of 6*l.* per acre, will be 225,000*l.*, which would amount to 12*s.* per house.

What were the charges of the London companies for supplying Sydenham with water?—Their works have not yet been carried out to Sydenham.

What is your estimate exclusive of house service?—At Sydenham 5*l.* per house, that is the capital expended.

What extent of ground having similar advantages with respect to

gathering grounds have you observed near the metropolis?—I am not aware of any ground possessing so many advantages as a gathering ground as Richmond Park, but there is a large extent of land within ten miles of the metropolis that might be made available for that purpose. Mr. Donaldson.

What is the total amount of acreage it would form?—About 10,000 acres.

Mr. Thomas Lovick, examined.

You are surveyor to the Metropolitan Commission of Sewers?—I am one of the surveyors. Mr. Lovick.

And before, you had practical experience with branches of works that involved the consideration of hydraulics?—Yes, in surface drainage, plumbing, and house-drainage works.

Before you were appointed to your present office, did you not institute an investigation into the condition of numerous houses in your parish?—Yes, by the direction of the paving authorities of St. Andrew and St. George the Martyr, in whose employ I then was. I made an investigation into and reported upon the sanitary condition of many houses in these parishes.

In the course of your investigation did you examine the water supply?—Yes, there was a section in my Report devoted to this subject.

You were directed by the Survey Committee and the Works Committee of the Metropolitan Commissioners of Sewers to take certain gaugings and carry out certain trial works to show the quantity of sewage, or soil water, and other matter which passed through the house drains and sewers?—Yes: the principal gaugings which I undertook were in a sewer receiving the drainage from nearly 1200 houses, for the determination, chiefly, of the quantities of house sewage discharged at different periods.

Then you have executed part and are conversant with most of the trial works carried on under the consolidated Metropolitan Commission of Sewers to determine the quantity of water discharged by pipes of different diameters, construction, and inclination?—Yes, I am generally conversant with them; I have examined many of the results, the works relating to the flow through different sized pipes under different circumstances were not, however, under my direction.

Among other experiments were you not directed to ascertain the quantity of water consumed in a given block of houses, as shown by gauging the capacity of their butts and cisterns, and also the quantity of soil water discharged from the same block of houses through the sewers?—Yes; the block to which my instructions had special reference consisted of nearly 1200 houses discharging through one main line of sewer. By gauging in the sewers the quantity of water passing through them from the houses at different periods was ascertained; and by gauging the cisterns and butts in the houses the actual *consumption* of water was arrived at.

Were there not difficulties in getting a block of houses where such gaugings can be carried on with certainty as to the results? State the

Mr. Lovick. difficulties of getting a proper site?—There are few such areas to be obtained sufficiently large for an average deduction where all, or nearly all, the houses are supplied with water on the same days, so as to ensure with certainty the separation of the overflow or waste waters from the sewage; receiving the drainage of all or of a sufficient number of the houses; where the drainage can be traced with certainty to the point at which the experiments are to be carried on; where there is no interference with, or check of, the flow of the outlet sewer by contiguous main lines, or by the action of the tides penning in the flow; and where land or spring waters are excluded.

What is the time in which 100 gallons of water, stated as being a day's supply to some houses, may be discharged through a 3 and a 4 inch pipe at a minimum inclination of 1 inch in 10 feet?—With pipes 50 feet in length, full at the head, at the given inclination, this quantity would be discharged through a 3-inch pipe in three minutes, through a 4-inch pipe in one minute and a half.

What are the observed effects of junctions in the flow of the main line?—Greatly to increase the flow in the main line.

Give in a block plan with the "lineage" of existing drains.—I beg to hand in a block plan of Earl-street, with an approximation to the existing drainage marked thereon.

Were these houses you have mentioned of the middle class?—A great number were; some were of a higher class, many of a poorer class, but the average would be a medium middle class.

State the quantity of water that on an average you found to be consumed there per diem?—The average consumption, as ascertained from gauging the cisterns and butts, was about 5·7 gallons per individual per diem, or $51\frac{1}{2}$ gallons per house per diem.

State the average quantity discharged per house per diem as produced from the gaugings of the sewers on days when there was no rain and no water supply?—$44\frac{1}{2}$ gallons.

State the average supply when the water was put on?—209 gallons.

From these gaugings did it not appear that the intermittent supply of water was twice as much as it need be?—The *mean* flow on the days when water was supplied to the houses by the company was nearly $4\frac{3}{4}$ times greater than the mean flow on the ordinary days, or days when there was no supply; the *excess* of the mean flow, or the flow due to the waste alone on the water days, would be nearly $3\frac{3}{4}$ times greater; but deducting the flow due to the ordinary drainage from the flow on the three water days, the waste would be three-fifths of the whole quantity supplied, and this would exhibit, leaving out of consideration the probable loss from absorption in both cases, the true relation of the consumption, as indicated by the gaugings in the sewer, to the waste. But as from the defects of the present system, from the numerous cesspools (at least 500 in this block), from the defective porous brick and mortar drains and sewers, a large amount of the flow must be absorbed in its transmission, both quantities, but more especially the waste, I have no doubt are much larger than the gaugings indicate. But leaving out any probable addition from this source, it appeared that the water supplied by the company was more than double the actual consumption, making the comparison between the flow in the

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sewer on the two classes of days, as each would be subject to the same influences.

You have prepared, we understand, diagrams of the flow observed in this block; give them in?—The alternations of the flow are shown in the accompanying diagrams. Diagrams Nos. 1 to 30 exhibit the daily flow at the periods of observation. Diagram A exhibits the greatest flow on water and ordinary days with the contrasted least flow, with the sectional areas occupied by the flow in the pipe, with the inscribed equivalent circular sections placed at the correspondent points of discharge. Diagram B shows the mean hourly and mean flows on water and ordinary days with the sectional areas and equivalent circles thus shown, this information being common to the whole tabular series. The lower horizontal line represents the hour-line, or period of observation; the vertical lines the discharge in cubic feet per minute. The extreme and mean variations of flow with the areas occupied are shown in the annexed table:—

Days.	Quality of Flow.	Cubic Feet per Minute.	Sectional Area of Flow in Pipe.	Diameter of Circles equal in area to the sectional area of the Flow.
			Inches.	Inches.
On water days.	Least . . .	1·07	1·66	1·5
	Mean . . .	26·46	27·94	6·00
	Greatest . .	150·00	109·79	11·8
On ordinary days.	Least . . .	1·78	3·05	2·00
	Mean . . .	5·64	8·57	3·4
	Greatest . .	16·90	18·14	4·9

The maximum being greater than the minimum—on the water-days 140 times, on the ordinary days 9½ times.

Does it not appear that the waste water pumped into this district exceeds the annual rain-fall within that district?—The waste water sent into this district would be upwards of 4½ million cubic feet per annum. This quantity would cover the area draining to the outlet sewer to the depth of nearly 30 inches.

From your own observations, do not these results show the waste of water that may be presumed as taking place in other districts?—I have hardly ever observed the present intermittent water-supply unaccompanied by waste: it may indeed be said to be a concomitant of the system. The waste in other districts I have observed to be very considerable; but except in one or two instances I have no gaugings, so as to speak to the quantities.

Did it not appear that, notwithstanding this flow of water at the rate of 209 gallons, accumulations took place in the house-drains and sewers: accumulations which had to be removed by hand labour or flushing?—Yes. In order to ascertain the extent to which this took place, and the influence of the waste in the prevention of accumu-

Mr. Lovick. lations, I had the whole of the sewers connected with this block thoroughly cleansed immediately before the commencement of the experiments, and their condition noted at their conclusion, and analyses made of the flow at different periods on the ordinary days and on water-days. The results of these analyses are shown in the subjoined tables:—

TABLES of SOLID MATTER in Suspension in the Flow.

No. 1.—*On the extra Water Days.*

Quality of Flow analysed, and period when taken.	Solid matter in one Imperial Gallon.			Proportions.	
	Soluble.	Insoluble.	Soluble and Insoluble.	Soluble to Insoluble.	Soluble and Insoluble to Liquid.
	Grains.	Grains.	Grains.		1 to
Greatest, taken at $5\frac{1}{2}$ P.M. . . .	33	19	52	.2 to 1	1346
Mean of two analyses taken at 12 A.M.	119	46	165	$2\frac{1}{2}$ to 1	424
Mean of two analyses taken at $8\frac{1}{2}$ and $10\frac{1}{2}$ A.M.	119	37	156	$3\frac{1}{4}$ to 1	448
Least, taken at 12 P.M. . . .	111	11	122	10 to 1	574
Total	382	113	495		
Averages	96	28	124	$3\frac{1}{2}$ to 1	564
When water first laid on, or at commencement of overflow from cisterns	80	192	272	1 to $2\frac{1}{2}$	257

No. 2.—*On Ordinary Days.*

Quality of Flow analysed, and period when taken.	Solid matter in one Imperial Gallon.			Proportions.	
	Soluble.	Insoluble.	Soluble and Insoluble.	Soluble to Insoluble.	Soluble and Insoluble to Liquid.
	Grains.	Grains.	Grains.		1 to
Greatest, mean of two analyses taken at 12 A.M.	114	34	148	$3\frac{1}{4}$ to 1	473
Mean, taken at $8\frac{1}{2}$ A.M.	154	71	225	2 to 1	311
Least, taken at 12 P.M.	114	14	128	8 to 1	546
Total	382	119	501		
Averages	127	40	167	$3\frac{1}{4}$ to 1	419

The approximate application of these results to the determination of the amount of solid matter passed in the flow may be thus shown.

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On water days the flow per diem was 38,102·4 cubic feet. The average proportion of the soluble and insoluble matter to the flow on these days was 1 in 564; the solid matter passed in suspension being 68 cubic feet per day, in proportions varying from 1 in 424 at the mean, to 1 in 1346 at the greatest flow, and in varying proportions of the soluble to the insoluble matter of from 2 to 1 at the *greatest*, to 10 to 1 at the *least* flow. The water-days occur three times per week; the quantity of solid matter per week passed in suspension would therefore amount to 204 cubic feet. At the first commencement of the waste of water, or overflow from the cisterns, a remarkable difference is observed in the relative proportions, the solid then bearing a proportion to the liquid of 1 in 257, and the soluble to the insoluble of 1 to 2½—a result wholly at variance with the analyses at all other periods, which give *in every case* the soluble in far greater proportion to the insoluble, from a *twofold* to a *tenfold* ratio, thus showing an accumulation of deposit in the sewers or drains, or in both, which it required this increase of flow to set free. The mean flow per day on ordinary days was 8121·6 cubic feet, with an average of soluble and insoluble matter in suspension of 1 in 419; the solid matter passed in suspension being 19 cubic feet per day, in proportions varying from 1 in 311 at the mean, to 1 in 546 at the least flow; the two classes of solid varying from 2 of soluble to 1 of insoluble at the mean, to 8 of soluble to 1 of insoluble at the least flow. As there are four ordinary days per week, the quantity of solid matter per week passed in suspension would be 76 cubic feet. The whole quantity thus passed per week, or on the two classes of days—204 feet on the water-days, and 76 feet on the ordinary days—would be 280 cubic feet; the *quantity per day* on the water, as compared with the ordinary days, being upwards of three-and-a-half times greater, but of course less in proportion to, or more diffused in the flow. At the end of 31 days the sewers were found to have accumulated nearly 6000 cubic feet of deposit, or at the rate of 192 feet per day, and the accumulations in the drains must also have been considerable. But taking only the accumulation in the sewers, and assuming but *one-fourth* of this as *solid* matter, thus approximating it to the dry condition, as in the analyses, the quantity per week is 336 cubic feet; this, with the addition of the matter held and passed in suspension each week (280 cubic feet), would increase the amount of solid matter per week to 616 cubic feet, or, in proportion to the flow, of 1 in 238, the proportion deposited in the sewer being rather more than one-half of the total quantity. Thus it appears that the waste does exert a perceptible influence in the prevention of matter accumulated at ordinary periods, removing on the whole, taking it with the large reduction to its dry state, nearly three times more deposit than is passed in the ordinary flow; yet, notwithstanding, it is wholly insufficient to prevent far greater accumulations.

What is the present cost of keeping clear the sewer in Earl-street, by flushing and by hand labour?—The two systems—*keeping clear* by flushing, and *once cleansing* by hand labour and cartage—would hardly admit of a fair comparison. The flushing system is for the *prevention* of accumulations; the cleansing system waits for accumulations, and removes them (in general) only when the stoppage of the system

Mr. Lovick. compels it. This occurs in a great number of the sewers, notwithstanding the action of storms and of the waste water from the houses, which would periodically remove much of the lighter matter. But the quantity which had *accumulated* in the short space of time before named might be removed by flushing in this locality at about one-sixth or one-seventh of the cost of its removal by hand labour and cartage. But the cost of flushing, carried on as a *preventive* measure, would be at a much less rate.

Did you not, for the sake of the experiment, lay down in this sewer a 15-inch pipe; and with the same run of water did this 15-inch pipe keep itself clear?—For the purposes of the experiment, a 15-inch pipe was laid down in the sewer for a length of 115 feet, discharging into a tank formed to receive the flow. With the same run of water in the pipe as in the sewer, the pipe kept itself clear.

What is the probable sectional area of the drains in this block of houses?—596 feet.

What is the sectional area of the outlet sewer, and its proportion to the house drains?—The sectional area of the outlet sewer is 15 feet, or about one-fortieth the aggregate sectional area of the house drains.

Do you not consider that since the commencement of the Commission you have had sufficient experience of the run of water through 3 and 4 inch tubular house-drain pipes to speak with confidence of their power to keep themselves clear by the ordinary discharge of the soil-water or drain-water of the house?—A great number of small 4-inch tubular drains have been laid down in the several districts, some for considerable periods. They have been found to keep themselves clear by the ordinary soil and drainage waters of the houses. I would refer to 15 houses in the Cloisters at Westminster Abbey, which have now for upwards of 14 months been drained by small stoneware pipes, varying in diameter from 3 and 4 inches for the houses to 9 inches for the outlet, and which have acted and continue to act in the most perfect manner. I have been furnished by Mr. Morris of Poplar with accounts of blocks of houses in his district drained by small pipes: these are shown on the accompanying plans. No. 1 is a block of 12 houses in a court, six on each side; each six are drained *at the back* by one 4-inch pipe. They are connected with the closets, one to each house, to which the water *is not* laid on, the water being thrown down them by the inmates; the only other source of supply is from the overflow of the butts in the yards, yet the pipes have kept themselves clear from the period when first laid down, now upwards of 12 months since, to this time, and are still acting efficiently. Plan No. 2 shows various blocks with combined back drainage by small pipes. Some have connections with closets to which water is laid on; others take the overflow from privy cesspools; yet with all these disadvantages, and with the further one of inferiority in the pipes in the early manufacture, these combinations of back drainage have been, and are now, all in successful action; they have been laid down, in one instance for upwards of two years, in the majority for upwards of 12 months.

Then you have no doubt that pipes of this kind will keep themselves clear by the ordinary discharge of house-drainage?—I have not; as-

suming of course a supply of water, pipes of good form and material, properly laid, and with fair usage. Mr. Lovick.

You have had experience of blocks of houses where tubular drains have been laid down?—I have.

You were engaged in the Cloisters of Westminster Abbey, on a block of houses, in laying down a set of tubular drains in the place where epidemic fever had broken out, and where it was supposed to have been caused or aggravated to its fatal extent by an accumulated quantity of decomposing cesspool matter underneath the foundations of the houses? —Yes. I was engaged under the direction of the Consulting Engineer to the Commission, Mr. Austin, upon this work. There were 15 houses in two blocks; each block was separately drained by one main pipe 9 inches in diameter, this being the largest size used, the sizes gradually decreasing to 4 and 3 inches for the minor branches.

How many loads of decomposing matter were taken from the drains of these 15 houses?—Upwards of 400 loads from the drains and sewers serving the 15 houses, and 120 loads from the cesspools, or upwards of 500 loads in all.

To what extent were the drains choked up?—Many were three parts full, some even more.

What was the area of evaporating surface of the drain or sewer and cesspools connected with this block of houses? Did you not put down a system of tubular house-drains after abolishing the cesspools there?—The area of evaporating surface of the sewers connected with this block of houses would be about 3000 feet; of the drains and sewers 4300 feet, with the cesspools in addition 4800 feet. The cesspools were abolished, and a system of tubular house-drains substituted.

What was the size of the old house-drains, and the new house-drains substituted for them?—The smallest observed house-drain was 9 inches square, the largest 2 feet in diameter, the house-drain substituted for them 4 inches in diameter.

What were the sectional areas, and sectional areas of friction, of the old house-drains and the new?—The sectional areas are, of the 9-inch square drain 81 inches; the 2-foot circular old drain 453 inches; of the new 4-inch pipe 12½ inches; or the smallest drain would be 6½ times, the largest 36 times greater than the new drain substituted for them. The frictional line, or interior perimeter of each drain, is 36 inches for the 9-inch drain, 75 inches for the 2-foot drain, 12½ inches for the 4-inch pipe; or the smallest old drain three times, the largest six times greater in this respect than the 4-inch pipe.

How long have the latter been now in action?—14 months.

Has the working of these new tubular drains been carefully examined? —Yes. In a Report made in June last on this block by Mr. Austin and myself, we state, "The delay has afforded us the satisfaction of reporting at the same time the complete success which has attended this work. The Dean of Westminster gave special instructions to the Clerk of the Works, resident in the Abbey precincts, to examine and report the condition of the drainage weekly; and not a single case of complaint has occurred during the whole period, except from an inconvenience which arose from the want of a connection to a water-closet not known of at the time, and therefore not provided for. One

Mr. Lovick. of the 4-inch branches has recently been opened to make this connection, and it was found as perfectly clean as when first laid down." The Dean of Westminster, in a letter on the state of this drainage, says, "I beg to report to the Commissioners that the success of the entire new pipe-drainage laid down in St. Peter's College during the last 12 months has been complete. The Clerk of the Works has examined every water-closet once a-week, and entered his written report in a book laid every Wednesday before the Dean and Chapter, and not one case of failure or imperfect working has occurred. I consider this experiment on drainage and sewage of about 15 houses to afford a triumphant proof of the efficacy of draining by pipes, and of the facility of dispensing entirely with cesspools and brick sewers." And up to this time they have acted, and continue to act, perfectly.

You made a joint Report with Mr. Austin upon this block of houses; will you state the results of that Report?—Yes. The old and the new systems are shown upon the two plans accompanying this Report. These will give some idea of their relative magnitude and construction. At the outlet the main sewer in the old system was 4 feet high by 3 feet 6 inches wide, varying in width to 6 and 7 feet, and in height in one part to 17 feet. Under the school the soil stood 9 feet deep. In the new drainage substituted there are two 9-inch stoneware mains, the united sectional area of which is but 1-16th of the area of the smallest part of the old sewer, and not more than one-half the area of the average of the single old house-drains. We state, "The secondary pipes are of 6 inches diameter, and the branches of 4 and 3 inches; 4-inch pipes were, however, used in many parts where 3-inch would have amply sufficed for all the requirements of the drainage, from an apprehension that the irregularity of the pipes would tend to create a certain amount of obstruction. The utmost pains were taken to secure the very best materials, and a great number of imperfect pipes were rejected and removed from the ground. The very best, however, were far from what they should have been; and we regret to say that now, a twelvemonth later, the manufacture appears not in the least degree to have advanced in quality; on the contrary, it would seem that the great increase of demand has been met by slovenliness and overhaste in execution, instead of by the application of machinery and improved appliances to the manufacture. This new drainage conveys the refuse and rain water from 15 houses, the Westminster School buildings, the Chapter-house and Cloisters of the Abbey, Little Dean's-yard, &c., comprising an area of about 2 acres. There is a total length of drain of upwards of 3000 feet. The cubical capacity of the interior of the *whole* of the new main and branch drainage is about 1-32nd part of the cubical capacity of the interior of the old sewers; or the capacity of *a portion of the old system* is 32 times the capacity of the *whole of the new system*, exclusive of the old house-drains and cesspools, or the capacity of the old sewers is equal to a depth of water of more than 2 inches on the whole surface drained of about 87,120 square feet, or 2 acres; or they would have retained a rain-fall of this depth on the whole area. The total cost of emptying the old sewer and cesspools (which was done without the slightest annoyance) amounts to 70*l.* 6*s.* 6½*d.*, which, including the extra labour of clearing the new drain, is at the rate of 2*s.* 8½*d.* per cubic yard. A flushing apparatus

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was fixed to one of the main lines; this is frequently used, but the water discharged bears no evidence of any tendency to deposit in the drain and the other line which there is no opportunity of flushing is equally clear. We have not experienced, since the completion of this work, one of those extraordinary storms which occur only at intervals of years; but the result of very heavy falls of rain, which we have experienced on more than one occasion, is sufficient security on this point. At no time has either main been half charged; proving beyond a question, from the quantities discharged, that, with the increased run from the pressure in the mains when flowing full, they would be of ample capacity to avoid flooding from the greatest storm of rain hitherto recorded. Although a great number of cases of combined back drainage have already been applied for, and granted, this is the only case of any extent which has as yet been entirely laid under the superintendence of the officers of the Commission, and thus security afforded that the house branches were correctly laid, and the inlets properly protected. We fear that, had it not been so, we should not have had so satisfactory a report to make of its working; for, with the multitude of connections belonging to this drainage, it is scarcely probable but that some obstructions would have taken place in them before this, had not this point been strictly attended to; and there is every reason to fear that, unless the same security is invariably adopted, the drainage never can work satisfactorily. We call attention to this case, however, as a favourable specimen of tubular drainage only so far as the materials would allow, and not by any means as we would desire to see it either as to workmanship or cost. There are many imperfections in the pipes themselves, in the curves, in the junctions, and in the inlets; there are many 4 and 3 inch pipes used where 3 and 2 inch would have been better, if better materials had been at command; and there were many additions thus made to the already extravagant price of the pipes. Our only hope of a better result in this respect is in the special attention of the committee appointed to investigate this branch of the subject." The working of this system, as appears by the Dean's Report, and as I am informed by others, and from my own observation, has been completely successful. The smells, which were very prevalent under the old system, have not been experienced under the new, and I am informed that during the past year, a year of great mortality, this place has been remarkably exempt from sickness.

Does this experiment leave any doubt on the mind of yourself, and of other officers, that under a tubular system of drainage, properly laid down, there would be no decomposing refuse remaining under the houses?—It does not; nor in that, I believe, of others with whom I have conversed. There were many sceptics at the time who have now become converts to the system from seeing its successful action.

In the case of the block of houses in Earl-street, was not the drainage upon the old system from the back to the front of the house?—Yes; from the back to the front of the house.

Now, if instead of being so drained it had been drained from the back by earthenware tubular pipes, what would be the decrease in the sectional area of friction by draining them at the back; what would be the gain in fall from each house as compared with the old system and the present system?—The decrease in the frictional area would be

Mr. Lovick. five-sixths; the gain in fall, by draining at the backs of the houses instead of through each house, would be in the main line one-half, in the house drains three-fourths.

It follows then, does it not, that if the house-drains keep themselves clear and the sub-mains also, with the increased force gained by junctions at the proper inclinations, the mains also would keep themselves clear by the ordinary supply of their own water even in dry weather, and that there is no need whatever under such a system for additional supplies of water either for flushing or for keeping the drains clear of deposit?—In a system of house-drainage properly proportioned and laid at a due inclination, if the single house-drains, the branches and sub-mains, with the ordinary supply of water, keep themselves clear in dry weather by the continual concentration and acceleration of the flow, it follows that by preserving a due proportion in the sizes to the flow and in the inclinations of the mains, and with the increased force gained by proper junctions, the mains would keep themselves clear under similar circumstances, and that in such a system of house-drainage no additional supplies of water would be requisite for that purpose.

Under this system, and in this particular block of houses, supposing it were back-drained with tubular drains, what would be the greatest length of time that any decomposing matter discharged through the house-drains would remain beneath the site until removed into the trunk-main? what is the ordinary rate of discharge from any given point per hour?—I believe it may be safely estimated that, with the inclinations at command, the sewage would be removed from the extremity of the district, in the system described, into the main-trunk at this flow in a period not exceeding 15 minutes. The rate of discharge along this line at the period named would not, I think, be less than three miles per hour; but this would be subject to infinite variations as the pipes were more or less full, or subjected to the influence of pressure.

On the whole, then, it appears from these experiments to be within the power to have all the house refuse of the metropolis constantly removed at a rate of not less than three miles per hour?—Yes, with similar inclinations, and under like conditions; but with many of the present outlets this, of course, is not possible.

What is the expense per house of back drainage, and what would it have been if tubular drains had been carried through each house separately?—The expense per house in this locality of tubular back drainage, including the closet-pan, &c., would be about 4*l.* 8*s.*, of tubular separate drainage from the back to the front of each house about 8*l.*, or nearly double.

What would be the proportional increase of the sectional area of friction?—The increase in the area of friction of the separate drainage *through* the house over the combined drainage at the back would be *two-fifths;* but the area of frictional surface opposed to the flow would vary with the flow.

What would it have been if the houses had been drained by the old system?—The increase in the area of friction, or interior surface area, of the existing system of large brick sewers through each street, with separate large brick drains through each house, over the combined small tubular drainage at the back, would be five-sixths.

What would be the annual expense of the proposed new branch main sewer as compared with the annual expense of the old sewer?—I do not apprehend that there would be any, so-called, annual expense connected with new sewerage works, if properly formed in the first instance. The annual expense or cost upon the present brick sewers in this locality, if kept cleansed by flushing, would probably be about 36*l*. Mr. Lovick.

What would be the expense of carrying the distributary water apparatus to the backs of the houses, on a constant system of supply?—2*l*. 8*s*.

At what would you estimate the extra expense of butts and cisterns for putting down the water-supply *de novo* on the intermittent system in this district?—The cost of providing adequate slate cisterns with the present supplies would be in this locality not less than 3*l*.

What is the proportion of the expense incurred in earthwork, simply in house-drains and others?—This will vary in localities, and according to the system pursued, and the depth at which the drains are required to be laid. The proportion of expense to the total cost would be in this locality, under the existing system, nearly one-third; under the separate tubular system, between one-half and one-third; under the combined back tubular system, nearly one-half.

Supposing, as it has frequently been considered necessary that the water-pipes should not be laid at a less depth than 3½ or 4 feet for the sake of coolness, what would be the advantage of laying the drainage and water-supply pipes together at the back? What would be the gain by the combination, or what the loss by the separation of these works?—The advantage of laying down the water-pipes and the drainage together at the back would be the saving of earthwork to the depth at which the pipes were laid, and of the paving and walls disturbed. Supposing the drains laid to a depth of 8 feet, and the water-pipes to a depth of 4 feet, the gain in saving of expense would be upwards of one-fourth on the water-supply, and nearly one-eighth on the combined works; and there is the further gain in the combination of works by one superintendence of the whole, instead of a double superintendence, which would be the case in a separation of works; and there is freedom from the annoyance of two disturbances of the premises, almost inseparable from the independent works.

Second Examination.

You were directed to examine the latest Report (1846) made to the Old Westminster District Sewer Commission under the Westminster Commission as to the means of improving the drainage of courts made shortly before the appointment of the Consolidated Commission?—Yes.

State the sizes of drains there contemplated, and what sized sewer?—The Report states that "three sizes of sewers should be used for that purpose, as represented by the sections numbered 1, 2, and 3. The first is intended for courts from 300 to 450 feet long, the second from 150 to 300 feet long, and the third for places 150 feet and less in length." They are egg-shaped in section. The sizes are 1 foot 9 inches by 3 feet 3 inches; 1 foot 6 inches by 2 feet 9 inches; 1 foot 3 inches by 2 feet 3 inches. The house-drains were of pipes 6 inches in diameter.

Mr. Lovick.

What was the common practice before the period of the publication of this Report?—The common practice prior to this Report was to construct large brick sewers adequate for the drainage of large areas, 5 feet 6 inches high by 2 feet 6 inches in width, with upright sides, curved top, and with a slightly-curved invert. The house-drains were either square or circular, 12 and 9 inches in width or in diameter, formed of brick and stone: 9 inches was the smallest size permitted to be used.

What would have been the expense per house upon that (the old) system?—About 11*l.* 5*s.*

What would be the rate of expense per house upon the improved system of back drainage?—About 1*l.* 7*s.* 3*d.*

What also would have been the expense of the system proposed in 1846, and the proportionate cost of the other systems?—About 5*l.* 4*s.*; or this system would be four times, and the old system eight times greater cost than the improved system of back drainage. The adjuncts of closets and sinks are excluded in these estimates, so that they might rest upon the system in regard only to the drains and sewers, but the proportions would be but slightly affected by their addition.

Give a comparative view as to the relative proportions, the economy, and the efficiency of these systems, viz., of the old system, of the system proposed in 1846, and of the new system of improvement by back drainage, in pursuance of the principles deduced by the investigations of the Metropolitan Sanitary Commission?—The diagrams handed in illustrate the comparative proportions of the three systems, and will elucidate their further description; taking the three systems in their several relations to each other:—

	On the Old System. / Improved System of 1846.	Old System. / Improved System of 1849.	Improved System of 1846. / Improved System of 1849.
The lengths are as . . .	1 to 1	$2\frac{1}{4}$ to 1	$2\frac{1}{4}$ to 1
The inclinations of main sewers are as	. .	. .	2 to 1 nearly
The inclinations of house-drains are as	. .	. .	1 to 10
The sectional areas of mains are as	$2\frac{1}{2}$ to 1	30 to 1	$11\frac{1}{2}$ to 1
The sectional area of the single house-drain is as .	$2\frac{1}{4}$ to 1	10 to 1	4 to 1
The capacity (cubical) of whole system is as . .	$2\frac{1}{2}$ to 1	37 to 1	$14\frac{3}{4}$ to 1
The cost is as	2 to 1	8 to 1	$3\frac{3}{4}$ to 1

Thus, in the system of 1846, the sectional area of the main is $11\frac{1}{2}$ times greater than the sectional areas of the mains according to the most improved practice, and its cubical capacity $14\frac{3}{4}$ times greater; the cost of the system being $3\frac{3}{4}$ times greater. The system of 1846 would form a reservoir for a rainfall of 1 inch in depth on the whole area drained. In the old practice the sectional area of the main is 30 times, its capacity 37 times, greater than the new; and the cost 8 times greater. The three systems would retain a rainfall on the area drained of $2\frac{1}{2}$ inches, 1 inch, and one-fifteenth of an inch respectively. Thus the

economy of back-drainage, as compared with the separate system of a centre sewer through the court, with drains from and through each house, would be— Mr. Lovick.

	On the Old System.	On the Improved System of 1846.
In the length	$2\frac{1}{4}$ times	$2\frac{1}{4}$ times
Inclination of main sewer . .	. .	2 ,,
Inclination of house-drains . .	. .	10 ,,
Area of mains	30 times	$11\frac{1}{2}$,,
Area of house-drains	10 ,,	4 ,,
Capacities	37 ,,	$14\frac{3}{4}$,,
Cost	8 ,,	$3\frac{3}{4}$,,

Or four similar localities might be drained on the new system for the cost of one on the improved system of 1846, or eight for the cost of one on the old system.

State the comparative advantages of the back over the old and improved systems in regard to the acceleration of the flow, and the relative proportions of the flow in the two systems; and to the relief from stagnant refuse under the houses, and from the percolations into the strata?—The sewage in the new system has to move through less than one-half the distance than in either of the other systems, in a more direct course, with far greater inclinations, in contact with smoother surfaces, concentrated in smaller drains, and with curvatures at the junctions opposed to the entries at right angles in the other systems; thus it will be discharged in a proportionately less period. Experiments would be required to ascertain the precise effect of these improvements, but a moderate estimate would give the discharge from the houses on the new system in one-fourth the time of its discharge through the system of 1846; or the sewage in the one system would remain four times longer *under* or in the *vicinity* of the houses than in the other. In the old, porous, sieve-like system the whole of the sewage *would not* be discharged or flow uninterruptedly to its outlet; but the more liquid portions of the flow would percolate through the joints of the brickwork, be absorbed by the surrounding strata, and sap the foundations of houses, rendering them damp and unhealthy; and would frequently contaminate wells, and would deposit the more solid and offensive portions which remain *under* the sites of the houses, frequently generating disease, until removed by breaking up the drain. So that there can be no estimate of the period of the discharge of the *whole* flow in this system, as this is an impossible occurrence.

Of course the periodic cleansing of the old system would show a still larger economy in favour of the tubular back-drainage system?—The economy *in cost* of the tubular back-drainage system would be greater if the cost of the necessary periodic cleansing of this, the old, system was taken into account, for in this system accumulations would

Mr. Lovick. be forming almost from the first hour of its use, from the vast disproportion of the area to the flow; from the necessary roughness, irregularity of material, and formation; from the largely increased space through which the sewage has to pass; and from the diffusion of the flow over so many (in this case sixty-six) *separate* channels besides the main; whereas in the back system *two channels* concentrate the whole, accelerate it, and thus prevent accumulations.

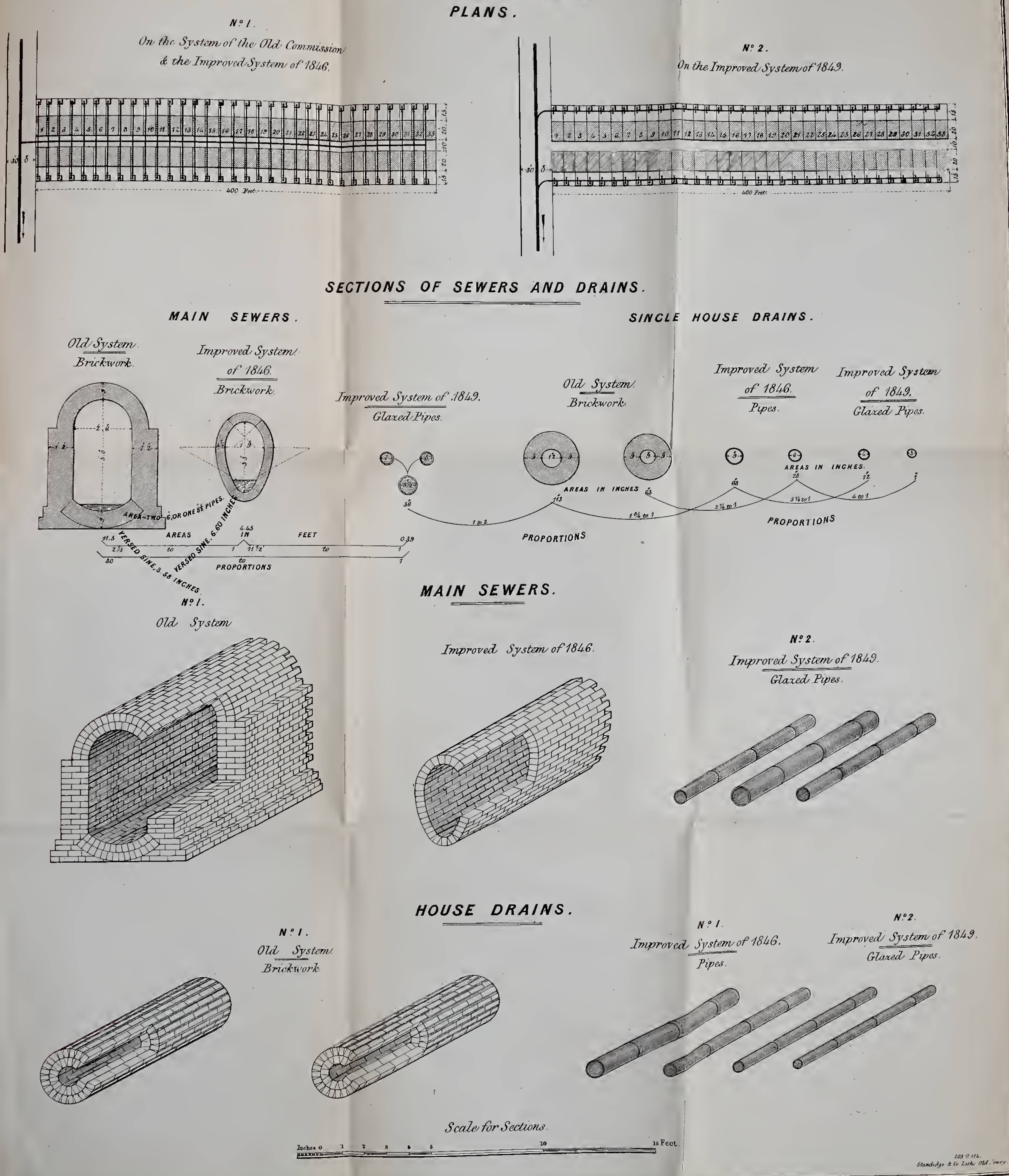
In the drainage through each house, would there not be danger from the emissions of effluvia *in* the house, which would not be possible under the system where the drainage was carried at the back, at the farthest distance from the house? Is not there in the back system less disturbance of the floors of houses and of the public streets? Give a synopsis of the two systems?—In the old system there would not be any security from annoyance, or even positive danger, from its favouring *to the utmost* the escape *in* and diffusion *through* the house of the deleterious effluvia, which, sooner or later, will be emitted, but which, by the system of back-drainage, even if loaded with all the old defects, would be largely warded off. The bulk of the drainage and the *most deleterious* portion is generated chiefly *at the backs* of the houses, and would, under the old system, be sent from thence *through* the house to the sewer *in front*, having to travel through the *greatest* possible space with the *least* possible velocity, and with the widest diffusion of the flow. In the formation of the system the disturbance of the flooring, joists, and walls of the houses, of the roadways and public streets, peculiar to this system, or of far greater amount than in the back system, to the annoyance of the inhabitants and interruption of public transit, is certainly a consideration of much weight. The system of back-drainage is in every respect the converse of this system and of all systems founded upon this principle, and is in every respect superior to them: for it receives the sewage at the *farthest* possible distance from the houses, instead of bringing it *into* and *through* them; concentrates and accelerates the flow in a few channels, instead of diffusing it over many, with, in many cases, scarcely an appreciable velocity; removes all the decomposing noxious soil and drainage from the houses as it is produced instead of, as in the old system, transmitting the liquids through to the strata, and retaining the solid and more offensive portions *under* and *around* the houses; is more easily executed, with far less trouble and annoyance, and at less cost; and practice has already established it as the most efficient.

Have you not practically found that 4-inch tubular pipes work best for house-drains?—Yes.

How much larger was the size of drains required for houses by the Building Act?—The *least* size required by the Building Act was *five* times larger.

Taking the block of twelve houses, drained by 4-inch pipes, which you have adduced as an example of the efficiency of small tubular back-drainage, state what would be the relative proportions of the system of drainage formerly practised in that district, and of the most approved system where the drains are carried through each house and where combined at the back?—The plan I now hand in shows the relative proportions of the systems referred to. In the old system there would be a large brick sewer through the centre of the court,

DRAINAGE OF COURTS, WESTMINSTER DISTRICT.



with large brick drains *through* each house. In the improved system the sewers and drains would be of small stoneware pipes, whether carried through each house or combined at the backs of the houses. The collective areas of the systems would be— Mr. Lovick.

The old	15·55 feet.
The improved (separate)	1·23
,, (back)	0·174

Or the old would be 13 times greater than the improved separate, and 89 times greater than the improved back system, and the improved separate 7 times greater than the back system. The capacities of the systems would be—

The old	835 feet.
Improved separate	52
Back	14½

Or the old 16 times greater than the improved separate, and 57 times greater than the back system; and the separate between 3 and 4 times greater than the back system. The systems would retain a rain-fall on the area drained of about 4½ inches, $\frac{1}{4}$-inch, and $\frac{1}{13}$ inch respectively.

What would be the proportionate cost per house of these systems?—The cost of the sewers and drains only, excluding the adjuncts of closets and sinks, in each system would be—

	£.	s.	d.
The old	7	14	6
The improved (separate) . .	3	1	10
,, (back) . . .	1	4	1

The old being two and a half times greater cost than the improved separate, and nearly seven times greater than the improved back system, and the separate nearly three times greater than the back system. With a velocity of only 3 feet per second, the extraordinary fall of rain of 2 inches depth on the area drained would be discharged by the small pipes laid at the back in twelve minutes, so that their adequacy to discharge the heaviest recorded falls of rain cannot be questioned.

Taking the water-supply to this block of houses, state the cost of the intermittent system as compared with the cost of the constant system, where the pipes are of lead and carried separately through each house?—Excluding the closet apparatus, the intermittent, 8*l*. 12*s*. 4*d*.; the constant system, 3*l*. 12*s*. 1*d*., or less than half.

Where the pipes are of iron?—The intermittent, 6*l*. 14*s*. 8*d*.; the constant, 2*l*. 11*s*. 6*d*., or nearly *one-third*.

Where the pipes are of stoneware?—The intermittent, 5*l*. 17*s*.; the constant, 1*l*. 18*s*. 4*d*., or *one-third*.

What would be the proportionate expense of the intermittent and constant systems, the pipes in both cases being carried at the back? Where the pipes are of lead?—The intermittent, 6*l*. 13*s*. 10*d*.; the constant, 1*l*. 10*s*. 9*d*.

Where the pipes are of iron?—The intermittent, 5*l*. 2*s*.; the constant, 18*s*.

Where the pipes are of stoneware?—The intermittent, 4*l*. 13*s*.; the constant, 14*s*. 2*d*.

State the proportionate expense per house of works on the intermittent system, where the pipes are carried through each house and where laid

Mr. Lovick. at the backs of the houses? Where the pipes are of lead?—Where carried through each house, 8*l.* 12*s.* 4*d.*; where taken at the backs, 6*l.* 13*s.* 10*d.*

Where the pipes are of iron?—Where carried through each house, 6*l.* 14*s.* 8*d.*; where taken at the backs, 5*l.* 2*s.*

Where the pipes are of stoneware?—Where carried through each house, 5*l.* 17*s.*; where taken at the backs, 4*l.* 13*s.*

State also the proportionate expense of works for water supply on the constant system, where the pipes are carried through each house from the front to the back, and where carried at the backs of the houses?—Where the pipes are of lead, on the separate system, 3*l.* 12*s.* 1*d.*; on the combined back system, 1*l.* 10*s.* 9*d.*, or less than half.

Where the pipes are of iron?—On the separate system, 2*l.* 11*s.* 5*d.*; on the combined back system, 18*s.*, or about one-third.

Where the pipes are of stoneware?—On the separate system, 1*l.* 18*s.* 4*d.*; on the combined back system, 14*s.* 2*d.*, or nearly one-third.

What would be the proportionate cost of the earthwork and making good on the intermittent and constant systems where the pipes are carried through each house?—On the intermittent system, 1*l.* 2*s.* nearly, or, in proportion to the total cost,

Where the pipes are of lead . .	12·7	per cent. nearly.
,, ,, iron . .	16·3	,,
,, ,, stoneware .	18·7	,,

Where the pipes are carried at the backs of the houses?—7*s.* 2*d.*, or, in proportion to the total cost,

Where the pipes are of lead . .	5·3	per cent. nearly.
,, ,, iron . .	7·0	,,
,, ,, stoneware .	7·7	,,

What would it be on the constant system, where the pipes are carried through each house?—1*l.* 2*s.* nearly, or, in proportion to the total cost,

Where the pipes are of lead . .	30·4	per cent. nearly.
,, ,, iron . .	42·6	,,
,, ,, stoneware .	57·2	,,

Where the pipes are carried at the backs of the houses?—7*s.* 2*d.*, or, in proportion to the total cost,

Where the pipes are of lead . .	22·4	per cent. nearly.
,, ,, iron . .	40·0	,,
,, ,, stoneware .	50·5	,,

Supposing these works of drainage and water-supply were executed simultaneously, what would be the gain per house; or what the loss, supposing them to be carried out independently?—The gain per house from the combination of these works would be, where the drains and pipes are carried through each house, 1*l.* 2*s.*; where carried at the back, 7*s.* 2*d.*; but the proportions of saving to the total cost would vary with the materials employed.

Thus, on the old system of drainage, under the intermittent system of water-supply, where the drains and pipes are carried from a centre

main separately through each house, the saving would be, where the water-pipes used were of— Mr. Lovick.

Lead	6·7	per cent. nearly.
Iron	7·5	,,
Stoneware	8·0	,,

Where the improved system of drainage was laid down at the backs of the houses with an intermittent supply of water, with the pipes also carried at the back in the line of the drains, the saving would be in this case, where the water-pipes were of—

Lead	4·5	per cent. nearly.
Iron	5·7	,,
Stoneware	6·1	,,

Where the system of water-supply is constant, dispensing entirely with the necessary adjunct of the intermittent system—the cistern, and where the drainage was upon the improved system as regards size and materials, but where the drains and pipes were laid from a centre main through each house, the saving would be, where the pipes are of—

Lead	16·3	per cent. nearly.
Iron	17·3	,,
Stoneware	22·	,,

But where in both cases the drains and pipes were laid at the back, the saving on these works would be, where the pipes are of—

Lead	13·1	per cent. nearly.
Iron	17·	,,
Stoneware	18·7	,,

The closets will be an additional expense of 14*s.* on the new system; of 2*l.* 4*s.* on the old system.

You were directed to prepare tables showing these results. Give them in?—I beg to hand in the following tables, which will give what you require:—

No. 1.—Of Water Supply and Drainage-works executed by independent authorities.

Per House.	INTERMITTENT.						CONSTANT.					
	Separate.			Back.			Separate.			Back.		
	Water Pipes of						Water Pipes of					
	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.
	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.
Water supply .	8 12 4¼	6 14 8¼	5 17 0½	6 13 10	5 2 0	4 13 0	3 12 1¾	2 11 6	1 18 4	1 10 9	0 18 0½	0 14 2½
Sewerage and Drainage .	7 14 6	7 14 6	7 14 6	1 4 1	1 4 1	1 4 1	3 1 10½	3 1 10½	3 1 10¼	1 4 1	1 4 1	1 4 1
Total . .	16 6 10¼	14 9 2¼	13 11 6½	7 17 11	6 6 1	5 17 1	6 14 0	5 13 4	5 0 2	2 14 9½	2 2 1½	1 18 3½

Note to this and the following Tables, Nos. 2, 3, 4, 5, 6, 7.—With the intermittent separate system of water supply the separate sewerage on the old system is placed. With the constant separate system of water supply the separate sewerage on the new system is placed. The improved back system of drainage is placed with the back system of water supply in both the intermittent and constant systems. In the first and seventh columns, under the head "Lead," the iron mains for the separate system under both modes, the constant and intermittent, are placed. The various description of pipes apply only to the water supply; two kinds of materials only being used for the drainage—brick and stoneware. And in these, as in the foregoing estimates, the closet apparatus is excluded.

No. 2.—Of Water Supply and Drainage-works executed by one authority.

Per House.	INTERMITTENT.						CONSTANT.					
	Separate.			Back.			Separate.			Back.		
	Water Pipes of						Water Pipes of					
	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.
	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.
Water supply .	7 10 5	5 12 9	4 15 1	6 6 7½	4 14 9½	4 5 9½	2 10 2	1 9 6	0 16 4½	1 3 6	0 10 10	0 7 0
Sewerage and Drainage .	7 14 6	7 14 6	7 14 6	1 4 1	1 4 1	1 4 1	3 1 10½	3 1 10½	3 1 10½	1 4 1	1 4 1	1 4 1
Total . .	15 4 11	13 7 3	12 9 7	7 10 8	5 18 10	5 9 10½	5 12 0½	4 11 4½	3 18 3	2 7 7	1 14 11	1 11 1

No. 3.—Of saving in the combined Execution of Works.

Per House.	INTERMITTENT.						CONSTANT.					
	Separate.			Back.			Separate.			Back.		
	Water Pipes of						Water Pipes of					
	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.
	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.
Works executed by independent authorities .	16 6 10¼	14 9 2¼	13 11 6¼	7 17 11	6 6 1	5 17 1	6 14 0	5 13 4	5 0 2¼	2 14 9½	2 2 1½	1 18 3½
Works executed by one authority	15 4 11	13 7 3	12 9 7	7 10 8½	5 18 10½	5 9 10½	5 12 0½	4 11 4½	3 18 3	2 7 7	1 14 11	1 11 1
Saving from combination of works, or cost of earthwork, making good the paving, flooring, &c.	1 1 11¼	1 1 11¼	1 1 11¼	0 7 2½	0 7 2½	0 7 2½	1 1 11¼	1 1 11¼	1 1 11¼	0 7 2½	0 7 2½	0 7 2½
Ditto, ditto, per cent. .	6·7	7·5	8·0	4·5	5·7	6·1	16·3	17·3	22·0	13·1	17·0	18·7

No. 4.—Of the proportionate Cost of Earthwork, making good the Paving, Flooring, &c., to the Water Supply.

Per House.	INTERMITTENT.						CONSTANT.					
	Separate.			Back.			Separate.			Back.		
	Water Pipes of						Water Pipes of					
	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.
	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.
Water supply, including earthworks, &c. . .	8 12 4	6 14 8¼	5 17 0½	6 13 10	5 2 0	4 13 0	3 12 1	2 11 5	1 18 4	1 10 8½	0 18 0½	0 14 2½
Earthwork, making good paving, flooring, &c. .	1 1·11¼	1 1 11¼	1 1 11¼	0 7 2½	0 7 2½	0 7 2½	1 1 11¼	1 1 11¼	1 1 11¼	0 7 2½	0 7 2½	0 7 2½
Percentage, nearly, of earthwork, &c., to total cost.	12·7	16·3	18·7	5·3	7·0	7·7	30·4	42·6	57·2	23·4	40·0	50·5

Mr. Lovick.

No. 5.—Of the proportionate Cost of Earthwork, making good the Paving, Flooring, &c., to the Sewerage and Drainage.

Per House.	Old System of large Brick Sewers and Drains.	New Tubular System. Where carried through each House.	New Tubular System. Where carried at the Backs of the Houses.
	£. s. d.	£. s. d.	£. s. d.
Total cost, including earthwork, making good, &c.	7 14 6	3 1 10	1 4 1
Cost of earthwork, making good, &c.	1 17 1	1 13 4	0 14 9
Percentage of earthwork to total cost	24	54	61¼

No. 6.—Percentages and Approximate Proportions of Cost of the Constant on the Cost of the Intermittent System of Water Supply.

Separate.			Back.		
Where the Pipes are of—					
Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.
41·8	38·2	32·7	22·9	17·6	15·2
or	or	or	or	or	or
$\frac{4}{10}$	$\frac{4}{10}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{6}$	$\frac{1}{7}$

No. 7.—Percentages and Approximate Proportions of Cost of the Back on the Cost of the Separate System of Water Supply.

Intermittent.			Constant.		
Where the Pipes are of—					
Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.
77·6	75·7	79·4	42·6	35·0	37·0
or	or	or	or	or	or
$\frac{3}{4}$	$\frac{3}{4}$	$\frac{8}{10}$	$\frac{4}{10}$	$\frac{1}{3}$	$\frac{1}{3}$

Third Examination.

You were directed to make experiments in cleansing by water by means of the hose and jet; will you state at what place you first carried them on?—Yes; the experiments were first carried on in Charles-street, Old and New Compton streets, Church-Passage, Dean-street, and Greek-street, Soho; subsequently in Church-lane, and four courts in St. Giles's.

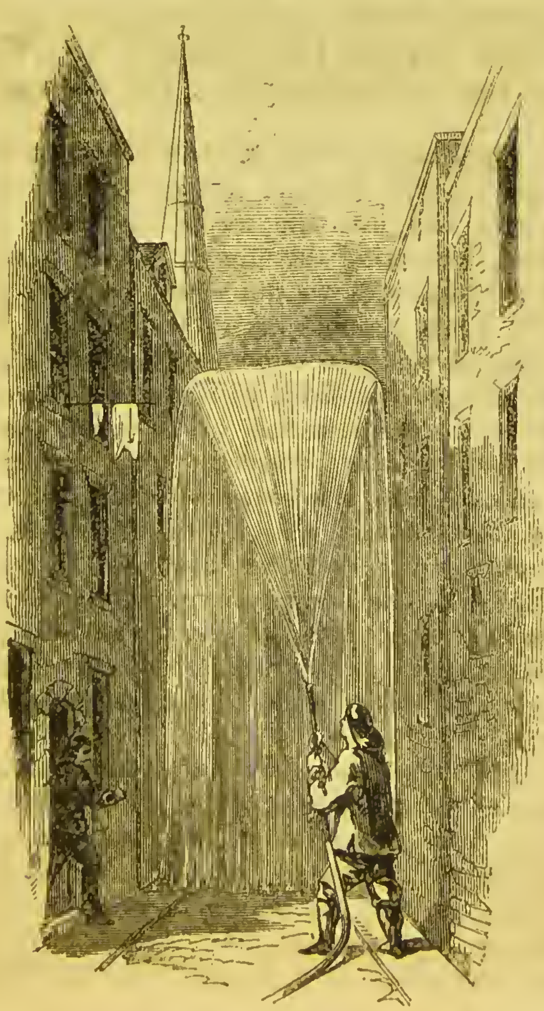
Were you not able not only to cleanse the pavements by this means, but also to cleanse the walls from urine stains and other filth?—Yes.

You were directed to prepare a sketch to show how the same plan can be carried out in courts and alleys. Give it in?—The sketches which I now hand in show the jet in operation. No. 1, is an illustration of the mode of surface-cleansing; No. 2, of the method of using the jet as a shower in close courts and alleys.

Mr. Lovick.

No. 1.

No. 2.



Mr. Lovick.

State the quantity of water used each time, and the expense?—The quantity of water used was nearly one gallon per square yard; the cost was at the rate of 9*d.* per 1000 yards, taking the cost of water on Mr. Wicksteed's estimate.

Then it is clear from your Reports that, in respect to economy of time and of money, it is superior and is more efficacious in removing surface-evaporating matter or filth than any other method?—In a Report to the Commissioners of Sewers I have estimated that the cost of the ordinary scavengering would be nearly double the cost of cleansing by the jet, and the jet has been shown to be far more efficacious in removing evaporating matter and filth.

You were directed to prepare an estimate of street-cleansing by these modes, as applicable to two large thoroughfares?—Yes; I prepared estimates of the cost of cleansing by the jet in the Strand and High-street, Borough.

Within what time and at what expense did you estimate this could be performed, apart from the cost of the water used?—The estimates were framed on the supposition that the work should be performed in one hour. In the Strand the daily cleansing of the carriage-way would have cost 3*d.* per house per week; in the Borough, 2¾*d.* per house per week. But this rate is for wide streets with a large amount of traffic, on data from experiments with very low pressures, and is greatly in excess of the ordinary description of works, and would by no means therefore be a criterion of the average expense.

What is the quantity of water required per square yard of pavement? The quantity of water required I have found to be rather less than one gallon per square yard of carriage-way; but this was with extremely low pressures.

Were not the experiments often made under what were considered other disadvantages besides those of low pressures?—They were; the pressures being very low, and the water having to pass through a great length of hose, decreasing the already limited power.

With a higher pressure may we not safely estimate that they might be performed with a less amount of water and in a shorter time?—Yes; I had occasion to compare some experiments in cleansing by the jet made by Mr. Lee, of Sheffield, with very high pressures, with my own experiments with low pressures, and I found that he could perform the work in less than one-third the time, at one-third the cost, and with less than one-third the expenditure of water. From this it would appear that the economy of high pressures must be very great.

What is the quantity that would have been used for the Strand for each complete cleansing?—By the latest experiments 18¼ thousand gallons.

In a day of partial rain, when the streets are sloppy and muddy, would not the cleansing by jet be the most eligible mode of cleansing? —The cleansing by jet on those days I consider would be by far the most eligible mode.

What was the effect in hot weather and at other periods of this new mode of cleansing as compared with the mode of cleansing by scavengering? What was your general conclusion from these experiments as to the effect of this mode of cleansing?—The cleansing by water produced a most perfect state of cleanliness by the removal of *all* decomposing refuse, and the jet, when directed upward in the form of spray, appeared to have the effect of a shower, the air being made much

cooler and fresher by it. The ordinary mode of cleansing by scavengering would have failed in removing much of the refuse, all of which the jet removed, and of course could not in any other way have improved the salubrity of the atmosphere. In hot weather these effects were more marked, the jet performing, but in a far more efficient manner, the office of the watering-cart. The ordinary mode of scavengering, without possessing any of the advantages of the jet, performed the work in a most imperfect manner. The system of cleansing by water eminently combined completeness with efficiency of action. Mr. Lovick

Even where it might be desirable to use a street cleansing machine to prevent accumulations of solid dung and the like, would it not be of importance to use the jet also?—In a Report upon this subject I have stated the general conditions wherein the combination of the two would be of advantage for this purpose, but that the machine should be auxiliary to the jet, than conversely as implied, in the following passage: "The frequency of application of this system (cleansing by jet) to the cleansing of the streets would be determined by their specific requirements, some, as the main thoroughfares, requiring daily cleansing, others cleansing at longer intervals. Thoroughfares having a large amount of traffic would require cleansing at an early period of the day; from this period to the cleansing on the following day the accumulations will have been going on and the exhalations from them discharging into the atmosphere. It may be necessary to employ measures for the prevention of this condition in conjunction with the systematic operations of cleansing by water. To effect this there are two methods, by sweeping with hand labour, and cartage of the refuse; by the cleansing machine; hand labour, when compared with the cleansing machine, would appear to be the least economical in the proportion, as stated in Mr. Whitworth's evidence, of about three to one. The machine therefore would appear to be the best adapted for this purpose, and with the least interference with the traffic of the street."

What is the total quantity of water, according to your estimate, that would be required for the purpose of street washing by means of the jet?—Assuming that there are 300,000 houses in the metropolis, with an average to each house of paved carriage-way 28 square yards, of paved footway 16 square yards (on data afforded by an average district, in the absence of other certain data), the area of carriage-way would be, in round numbers, 8½ millions, of footway 4¾ million square yards. With one gallon of water for each square yard of carriage-way (a proportion somewhat greater than I have found in practice with low pressures, and far greater than I believe would be the case with high pressures), and half a gallon for each square yard of footway, the quantity of water required for the *daily* cleansing of these areas would be nearly 11 million gallons, or 65½ million gallons per week, or a rate per house of 218 gallons weekly, or 36½ gallons daily. With a population of 7 to each house the rate would be nearly 5¼ gallons per diem for each inhabitant. Taking the cleansing of the streets in a ratio approximating to their specific requirements, about *one-third* daily, *one-half* twice, and the remainder *three* times per week, the quantity of water *per diem* would be 6·2 million gallons, or 20 gallons per house, or nearly 3 gallons per diem for each inhabitant. The following tables show the particulars more in detail:—

Mr. Lovick.

No. 1.—Of the Carriage-way.

Period of Cleansing per Week.	Quantities to be cleansed at each Period.	Total Quantities cleansed per Week.	Water required, in Gallons.			
			Per Week.		Per Diem.	
			For Quantities cleansed	Per House.	Per House.	Per Individual.
No.	Square yards.	Square yards.				
6	2,750,000	16,500,000	16,500,000			
3	1,000,000	3,000,000	3,000,000			
2	4,750,000	9,500,000	9,500,000			
	8,500,000	29,000,000	29,000,000	96·7	16·1	2·3

No. 2.—Of the Footway.

Period of Cleansing per Week.	Quantities to be cleansed at each Period.	Total Quantities cleansed per Week.	Water required, in Gallons.			
			Per Week.		Per Diem.	
			For Quantities cleansed.	Per House.	Per House.	Per Individual.
No.	Square yards.	Square yards.				
6	1,536,000	9,216,000	4,608,000			
3	576,000	1,728,000	864,000			
2	2,688,000	5,376,000	2,688,000			
	4,800,000	16,320,000	8,160,000	27·2	4·53	0·65 (nearly).

No. 3.—Of the Carriage and Foot Ways.

Period of Cleansing per Week.	Quantities to be cleansed at each Period.	Total Quantities cleansed per Week.	Water required, in Gallons.			
			Per Week.		Per Diem.	
			For Quantities cleansed.	Per House.	Per House.	Per Individual.
No.	Square yards.	Square yards.				
6	4,286,000	25,716,000	21,108,000			
3	1,576,000	4,728,000	3,864,000			
2	7,438,000	14,876,000	12,188,000			
	13,300,000	45,320,000	37,160,000	123·9	20·63	2·95 (nearly.)

It is stated that the quantity of water pumped into the metropolis is 50 million gallons per diem, or at the rate of 200 gallons per house?—It has been so stated.

Have you seen the estimate made by Mr. Mylne of the actual quantity of water consumed per house, taking the average of houses of different classes, and does that estimate correspond with the results of your own observations?—I have. My principal observations would refer to classes of houses (supplied by the West Middlesex Company) on an average somewhat higher than the medium between what Mr.

Mylne calls houses of the middle class and houses of the poor, having receptacles for water. These observations give an average consumption of 5·7 gallons per individual per diem. The mean of the two classes of houses in Mr. Mylne's estimate is 5·53 gallons per individual per diem, showing an accordance between them. Mr. Lovick.

What is the quantity, according to his returns, that would be used per house in the Earl-street district?—Taking the consumption as the mean of the second and third class houses in Mr. Mylne's estimate, the quantity used in the Earl-street district would be nearly 50 gallons per house per diem.

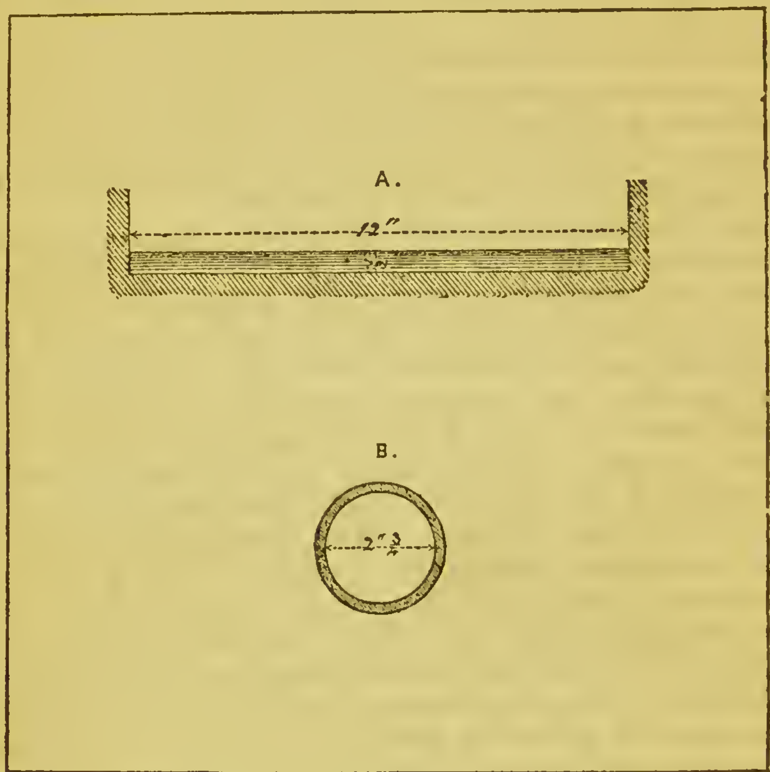
Supposing that 50 million gallons of water are at the present time supplied to the metropolis, would it not appear from the trial-works and observations that there is an amount of waste of more than one-half on the present system of intermittent water distribution?—The actual waste, from my observations, is three-fifths of the whole quantity supplied. On the supposition that the waste was in this proportion over the whole of the metropolis (and it would appear to be so), 20 million gallons would be the quantity used, and 30 million gallons the quantity wasted, of the 50 millions stated to be supplied.

Then from these trial-works and observations it appears that more is wasted than would suffice for the most profuse system of cleansing?—The system of cleansing must indeed be profuse that would require anything like the quantity wasted; but the application of the waste to surface-cleansing will best illustrate this point. The daily waste, or waste on the water day, in the Earl-street district is 187,000 gallons. This would cleanse the whole of the carriage-way on the area five and a half times, or the one day's waste would cleanse it nearly every day for six days in the week, or it would once cleanse a street 30 feet in width by 10½ miles in length. The weekly waste would cleanse *daily* the carriage-way of three such localities. Taking the same proportion of waste as applicable to the whole of the metropolis, the daily waste on the quantity stated to be supplied would be 30 million gallons. One-third of this waste would suffice for the daily cleansing of the whole of the carriage and footway paving, on the data before given, and about one-fifth where the periods of cleansing are proportioned to the specific requirements of localities; but the frequency of cleansing would considerably decrease the proportionate expenditure of water, and would reduce these proportions, which are founded upon the experimental first cleansing of streets.

Supposing you provided for a general supply of water, including general street-cleansing by use of the jet in summer, and presuming a general substitution of the soil-pan apparatus for cesspools, do you think it probable that the entire demand would be for more than two-thirds the quantity of water now stated to be supplied to the metropolis?—The quantity of water stated to be supplied is 50 million gallons per diem, at the rate of 200 gallons per house: this would indicate a supply to 250,000 houses. Taking the number of houses in the metropolis at 300,000, or 50,000 beyond the number which appears to be supplied, and a supply of 76 gallons per diem to each, as this appears to be the rate of consumption in the higher-class houses, we get the rate per diem of 22,800,000 gallons. For street-cleansing we have 36⅓ gallons per house per diem, or a gross rate per diem of 10,900,000 gallons, or for the domestic supply and for street-cleansing 33¾ millions

Mr. Lovick. nearly. Thus, with an average supply of 76 gallons per house per diem, the 300,000 houses would consume less than one-half the present stated supply to 250,000 houses, and with the addition of the quantity required for street-cleansing, about two-thirds; but the supply for manufactories, which I presume is included in the stated quantity, would require to be known, in order to see what is absolutely due to the house (or domestic) supply, and so to estimate its influence on these proportions.

State whether, from the trial-works and observations, it does not appear to be possible, by improvements in the construction of the pipes, to diminish the area of friction and increase the force of water, and thus reduce the necessity of additional supply?—The annexed diagrams



will illustrate the decrease in the area of friction with increase of height, and consequent gain of power by the adoption of pipes. Thus let A represent a square 12-inch drain, with a flow of water through it ½-inch in depth; the area of the flow will be 6 inches, the frictional surface in contact with it 13 inches. Introduce this flow into a pipe of equivalent sectional area, B, the height is increased nearly *six-fold*, whilst the frictional surface of contact is reduced *one-third*. But the water, *in rising* in the pipe, moves with an accelerated velocity: it would, therefore, occupy but a portion of the area of the pipe. Thus, in the case supposed, there might be a reduction in the size of the pipe, or a larger flow might be sent through it. In common drains of the kind in the example, the friction is greatly increased by the defective materials and irregularity of form. Mr. Roe has found the velocity in glazed pipes to be one-third greater than in brick-made drains (*vide* Evidence in First Report of Metropolitan Sanitary Commissioners). The common description of pipes are much superior in this respect; and, with the extension of improvements, they would possess still

further advantages. It is clear, therefore, that power is gained by the introduction of the tube; and as smoothness of surface and regularity of form lessen the friction, you further increase the gain by attention to these points; and it has been found where tubes have been introduced, even in cases where the supply of water has been scanty, that they have acted successfully. With the present supply of water properly distributed, in conjunction with a proper tubular system of drainage, you may no doubt greatly reduce the necessity for an additional supply for drainage purposes. Mr. Lovick.

Supposing the soil-water which is delivered be required to be pumped out in any direction, say on an average lift of 100 feet, what would have been the gain of engine-power by the reduction in the quantity of water needed by the most improved system of drainage and water-supply, as deduced from these trial-works and observations?—In the absence of information as to the quantity supplied to manufactories, there are no precise data for estimating it; but if we take the difference between the stated daily supply, 50 million gallons, and that stated as the required supply, 33¾ millions nearly—or 16¼ million gallons—the gain in engine-power, on the supposition that this quantity was raised in 12 hours, would be 683 horse-power.

Were not the earthen pipes first used very defective in construction?—Yes, they were very defective in construction, few approaching to anything like regularity of form—rough, ill glazed, and with many indentations and protuberances, which would greatly impair their efficiency.

Have you seen specimens of improved pipes, made with pressure, which give a greater regularity of flow? Does not the increased velocity amount to one-third, or one-fourth?—Yes.

With the extension of similar improvements, have you any reason to doubt that great increase in the velocity of discharge, compared with the present apparatus, might be produced, consequently reducing the need for additional supplies of water for keeping the drains clear?—Superior make and regularity of form of the pipes considerably reduce the friction, and promote greater regularity of the flow, and would accelerate it. In those specimens which I have seen, the acceleration is stated at *one-fourth*, a result obtained solely by improvements in the manufacture, by the extension of which I have no doubt but that a great increase in the velocity might be obtained.

What were the general statements as to the expense of the water-supply in several districts that were investigated?—In St. James's parish the average expense per house per annum, as returned by the occupiers of 1885 houses, was 3*l.* 0*s.* 2*d.* In St. Ann's, Soho, the average expense per house per annum, as returned by the occupiers of 1173 houses, was 1*l.* 17*s.* 5*d.* In St. George's, Southwark, the average expense per house per annum, as returned by the occupiers of 2064 houses, was 1*l.* 7*s.* 9*d.*

What was the average rate of expense for water as returned by the tenants of the 1100 houses in the Earl-street district?—The average rate of expense for water as returned by the tenants of 856 houses in this district was 34*s.* 1*d.* per house per annum.

It appears from the returns of the London and Vauxhall Company that there are some thousands of houses in their district without the means of receiving water, and that its very abundance is productive

Mr. Lovick. of evil in making the neighbourhood damp and unfit for habitation. Is the same remark applicable to other districts?—I believe it will, more or less, apply to all the districts. Although there are stringent provisions for the prevention of waste, as the Companies require proper cisterns and butts and ball-cocks to be provided, yet, from this regulation not being complied with, and from the defective working of the apparatus, either naturally or from design, waste occurs to an enormous extent, and in many situations produces the condition stated by the Southwark and Vauxhall Company as occurring so largely in their district.

You have, no doubt, observed, in cases where drainage is deficient, great dampness caused by the waste of water?—Yes, frequently. I am now in communication with an owner of property who proposes to lay on the water to several houses so soon as proper drains are provided for taking off the waste, and for which he has applied. He has stated to me that he would not lay on the water without the drains were first provided; and I have no doubt but that this consideration weighs with many landlords, as the injury arising from dampness caused by the water-supply, where drainage is deficient, is incalculable.

Have the earthenware sewer pipes which you have put down been in macadamised roads?—There have been some put down in roads of that description.

Have they had any protection from granite detritus?—Some of them have not.

And yet they have kept themselves clear?—In those cases in which the pipes have kept themselves clear there has been a good flow of water, and they are laid at a good inclination.

Does it not appear that with a good flow in the main-line if the stuff from roads was sent into it it would be carried off?—With the main-line laid at a due inclination, and with a good flow of water through it, the slop from the roads in wet weather would, I believe, be carried off; but hitherto there has not been a sufficiently large experience on this point to speak with absolute certainty.

Was it not considered desirable and practicable, nevertheless, to make shallow cesspits for the gully-shoots for roads, to prevent granite detritus from getting in?—It was, and very judiciously so, in the present arrangements and with our present experience on the subject.

But this is with a continuous fair fall; now, supposing the continuity of the fall to be interrupted by the outlet being below high-water mark, of course the matter which before was carried in suspension would be deposited?—As the power to remove matter in suspension is in proportion to the volume of water, and to the velocity with which it moves, and as this velocity increases with the increased inclination, any interruption of the fall or decrease of inclination must be attended with a proportionate loss of power, and this becomes progressive in sewers situate in districts below high-water mark, where the outlets are affected by the tide, so that where sewers pass through a district of this kind from a higher level the matter held in suspension in the flow in the higher parts is deposited as it is brought down into the lower level.

Is it not found that this detritus becomes indurated, and requires a greater force of water to remove it than that necessary to keep it in suspension?—Yes. The detritus will become so indurated as to require a very considerable force of water, and even manual labour

aided by proper implements to remove it, so that the force of water necessary to keep such matter in suspension bears but a slight proportion to the force requisite for its removal when it has once become indurated. Mr. Lovick.

In places which are below high-water mark for how many hours is the flow arrested?—This will vary in places. In some districts the flow would, on the average, be arrested for two-thirds of the day, or for 8 hours during the daily tides, or for 16 hours, taking the tides throughout the 24 hours.

Then, in consequence of the arrest of the discharge in these low-lying districts, a much larger volume of water is requisite to lift and remove the matter so deposited?—Yes. The quantity of water necessary to keep matter in suspension in lines laid at a due inclination, and, where the discharge is continuous, bears but a slight proportion to the enormous volume required to lift and remove the same matter after it has been deposited.

Supposing the additional quantity of water necessary to remove the deposited and indurated matter is to be sent in by pumping, would it not be a greater economy of pumping-power to lift the water from a lower artificial level, in order to preserve the continuity of the discharge? With a proper tubular system of house-drains and sewers, would it not be a large economy of power to pump?—If the supply of water now used for the prevention of accumulations of deposit in this district had to be pumped into the district, and if, as the question implies, an artificial outfall was to be provided, so as to ensure a proper tubular system of house-drains and sewers, or a system constantly discharging, the power requisite to pump the supply of water now used into the district for the prevention of the accumulations of deposit from the ordinary drainage in the present sewers would much exceed the power requisite to pump up the ordinary drainage from such artificial outfalls, much more would be the excess of power required were *additional* supplies of water pumped in for sewer-cleansing purposes.

You of course have had to flush the sewers in the Surrey and Kent district, and have observed there the effect of the intermittent discharges of the drainage matters which are backed up and kept within the district during high-water? In the discharge of the sewers there, is not the supernatent sewage water decanted off, leaving the matter deposited, and what are its effects?—Yes. From the drainage-matter in this district being locked in for many hours in each day, a very large proportion is deposited, and, when the outlets become free, then the liquid portion, with but a slight amount of the solid matter, is decanted off, or flows, into the Thames. And as the reservoir-sewers become full, the foul gas is expelled from them through every opening into the public thoroughfares and into the private houses. And the generation of foul gas is quickened by the stagnation of the drainage, being continually formed and continually expelled by the progressive accumulation, so that not only are mechanical difficulties created, but health is jeopardised by this arrest of the flow.

Have you estimated what would be the quantity of water required to flush away this matter?—It would be difficult to do so, as (owing to many of the collateral and parts of main sewers being below their outlets; to irregularities in them; and to the unavoidable deficiency of fall in even the best constructed lines, from much of the district being

Lovick

below high-water; and from the drainage being locked in by the tide about two-thirds of the time) it is impossible to remove much of the deposit from many of the lines. The present quantity of water, with the immense volume now procured from the Thames through the various sluices, probably at least from eight to ten times greater than the ordinary sewage-flow, is wholly inadequate to keep even many of the better class of the low-level sewers clean.

In that district it appears that there have been and are now daily presented demonstrations of the interruption of the flow of water, from the district being below high-water mark?—Yes.

In many instances are not some of the outlet sewers brought down to low-water level?—Some are brought down to within from 2 to 4 feet of low-water mark.

In respect to the pollution of the Thames water, have you seen a statement of the relative rate of flow of the tides?—Yes.

Take the case of sewer matter discharged—say at Rotherhithe—what would be the highest point up the river at which it would be safe to take the water for domestic use?—It is stated by some that the flood-tide continues for 7 miles, and the ebb for 10. Now if matter was discharged at Rotherhithe (say by the Thames Tunnel) at low-water, or the turn of the tide for flood, it would travel, supposing the whole mass to move, 7 miles up the river, or to nearly half-way between Battersea and Putney Bridge, and *above* the Counter's Creek sewer, the highest main outlet in the Westminster district of sewers, and considerably above the points from whence the Southwark and Vauxhall, and Chelsea water companies at present derive their supplies; so that, if water is required for domestic use, uncontaminated by sewage matter, it could not be taken, at least during certain periods, from any part between these points; but this is without reference to matter discharged at higher points, which at present contaminates the river far above these limits, and this is daily increasing with the extension of the town westward. For instance, the Counter's Creek sewer, which a few years since discharged but little else than land waters, and was so instanced before the committee on the Metropolis Water Supply so late as 1834, now receives a large amount of house-sewage, which is rapidly increasing from the rapid extension of buildings on this area. Upon the rates of the tides, and their proportions to each other, there are various conflicting statements, so that they can only be very approximately stated, and must be received merely as rough approximations to illustrate the principle of the tidal action.

How many loads of sewer deposit have been removed in any one week in the Surrey and Kent district? What is the total quantity of deposit removed in any one week in the whole of the metropolitan district?—It is difficult, if not impossible, to ascertain correctly the quantity removed, owing to the variety of forms of sewers and the ever-varying forms assumed by the deposit from the action of varying volumes of water; but I have had observations made on the rate of accumulation, from which I have been enabled roughly to approximate it. In one week, in the Surrey and Kent district, about 1000 yards were removed. In one week, in the whole of the Metropolitan districts, including the Surrey and Kent district, between 4000 and 5000 yards were removed; but in portions of the districts these operations were not in progress.

Does not the flow tend to form channels in the deposit, proportioned

to its volume? Give cross-sections illustrative of this point?—Yes; the sections which I now hand in show that this is so. (*See* Plan.) Mr. Lovick.

Are not these channels frequently curved, and do they not frequently indicate the proper proportion of passage to the volume passing through them?—They do.

In the performance of your duties in the direction of flushing operations, you will have observed the points of discharge or the outlets of the main lines of sewer flushed. You were directed to observe, as far as you might have opportunity, the range of contamination of Thames water from such flushings. Describe them?—It would be difficult to except any part of the Thames within the influence of the tides from the range of contamination from the flushings of the sewers into it, or from their natural discharges; many of the main outlets being high up the river. In the Report of the Committee of the House of Commons on the Metropolis Water Supply, in 1834, an experiment to ascertain the rate of flow of the tide is recorded. A float was placed by the King's Scholars' Pond sewer at the commencement of the flood, during or near a spring-tide, which travelled nearly half a mile above Kew-Bridge; the actual distance travelled being 10½ miles in five hours and nine minutes. The King's Scholars' Pond sewer is not the highest large *main* sewer on this, the north, side of the Thames; the Ranelagh sewer, draining a larger area and receiving a very large amount of house-drainage, and the Counter's Creek sewer, being above it; but this will give some idea of the range of contamination.

You were directed to take the highest sewer and the lowest sewer outlet into the river Thames, under the jurisdiction of the Metropolitan Commission of Sewers, and, supposing the discharge of each sewer at the usual time after high water, delineate the progress or the extent of flux and reflux of the sewage, until its final exit from the populous portions of the bank of the Thames, as (say) Erith or Woolwich; or, supposing a floating body to be discharged from the sewer, mark its track of flux and reflux?—The flux and reflux of the river, in its effect upon any floating body discharged into it, may be best shown (although, for the reasons before stated, this can only be approximately done) by considering the discharge to take place at the extreme limits—of the flux in the one case, of the reflux in the other: assuming the tides to be, as they are generally stated, in the following proportions—the flux to run 7 miles, or 5 hours; the reflux 10 miles, or 7 hours; and that the whole mass moves.

The diagrams A and B will represent the discharges as affected by these two conditions.

The black lines show the flux and reflux; O the floating body at the moment of discharge; and the black dots the same body at different stages of the tides.

Take the discharge at high water, as in diagram A.

In 7 hours the float has travelled 10 miles *down* the river, in 12 hours it has returned 7 miles *up* the river, or to within 3 miles of the point of discharge. At the 31st hour it is 16 miles down the river, and has returned at the 36th hour to within 9 miles of, or is removed that distance below, the starting-point.

Take the discharge at low water, as in diagram B.

Supposing the most valuable manure were to continue to be wasted,

Mr. Lovick. at what time and at what point, by pumping, might the sewage-water of the south side of the river be discharged apparently safe: that is to say, safely from the pollution of the river or banks within the densely populated districts? At what point from the north side of the river?—The period at which the sewage might most *safely* be discharged would be at high-water, or the turn of the tide for ebb, as it would then be removed the furthest distance from the town in the shortest time; and assuming the correctness of the statement, that there are 3 miles in favour of the ebb, the sewage would in the one tide be permanently removed 3 miles below the point from which it was discharged. The discharge at low water, or the turn of the tide for flood, would require seven tides, acting over a period of 41 hours, to produce this effect, according to the proportions of the flood and ebb which have been generally given. Greenwich on the south side, and Blackwall on the north side, may be considered as the limits of the densely populated districts; but on the south side, below Greenwich, is Woolwich. The limit of density of population at the point lowest down the river, whether on the south or on the north side, should govern both sides on this question, as the point which might safely serve one side might endanger the other, if situate lower down on the opposite side, the sewage flowing from both sides into the *one main* channel. So that if the extreme point be taken, and the discharges considered as taking place at high water, the river at Blackwall would be the point for both sides; although for the south side a shorter course could be taken, which would for this side take the sewage about one mile lower down the river.

Mr. John Grant, examined.

Mr. Grant. Are you not surveyor to the Metropolitan Commissioners of Sewers?—Yes: for a considerable portion of the Surrey and Kent district.

Had you previously executed works of drainage yourself?—I had.

Have you had experience of the practical working of tubular drainage?—Yes.

From what you have seen are you convinced that these drains will keep themselves clear if on a proper inclination?—I am. Within the last few weeks I sent to know how the 4-inch drains I had put in at Exeter, twelve and eighteen months ago, had answered, and in every case I found that they had done so perfectly, notwithstanding that some of them had been put down without water supply. The parties concerned are perfectly satisfied with them.

What is the largest number of houses in one block that you have drained on the tubular system?—130 for one gentleman, but it was not convenient for him at the time to lay on water. The drains have, however, acted well, notwithstanding the risk thereby incurred.

On your appointment as surveyor under the Metropolitan Commissioners of Sewers you were directed to examine and report on the working of the earthenware tubular drains, which had been ordered by the new commission of sewers to be laid down?—I was.

Most of those works had been combined with the service of water-supply?—In most cases they had: but in some they had not.

It will be seen that the float has been brought back five times to the point from which it was first discharged, after having travelled to the point of last coincidence 42 miles through six tides. So that the float is permanently carried, at high water, in six tides, extending over 36 hours, 9 miles below the discharging point; at low water, in seven tides, extending over 41 hours, two miles *below* it. Or to produce the effect of the discharge at high water it would require twelve tides acting over a period of nearly 66 hours, through a space of 93 miles, on the supposition, as before, that these quantities approximately represent the rates and proportions. Mr. Grant.

The outlets of the sewers are at points *intermediate* between high and low water, so that the discharges will be at various stages of the tides, carried *down* a less distance in the *reflux*, carried *up* a less distance in the flux, oscillating proportionately between the limits of the flows; but the diagrams will serve to show the general action of the tides in the simplest manner.

From these observations you are enabled to speak from the demonstrations of trials, made under varied and disadvantageous circumstances, as to the extent to which the present supplies of water may be made to act for cleansing?—Yes.

Since the house-drains, when properly laid, are kept clean by the action of the waste water which they have to discharge, may not the junction or the branch drains be expected to keep themselves clean with their reduced amount of friction, and even with reduced falls?—They may.

As a matter of fact, where the drains and junctions are tolerably well laid, do they not keep themselves clear of accumulation, and consequently need no additional supplies of water?—They do.

When you speak of the tubular drains, are not the pipes at present and hitherto manufactured very imperfect?—They are, both in form and finish. A great many of the quality called "seconds," as well as of common red clay pipes, are used by private bricklayers when they can escape supervision.

Do not the potters continue to make right-angled junctions, and other improper forms of pipes?—Yes; because the importance of better forms is not generally understood, and a trifling saving of 9*d.* per pipe is made by using a straight in connexion with a right-angled pipe, instead of a curved with an acute-angled junction.

Will a 4-inch tubular drain take off the water falling upon the roof, and yard as well as that coming from the interior of a house of the largest class?—It will, if properly laid at an inclination of not less than 1 in 120.

What number of fourth-class houses may be drained by a 4-inch drain?—This will vary with the inclination and the extent of ground attached. In 1848 I drained five houses through such a pipe, and it has answered ever since perfectly and without any stoppage. Since then I have laid out the drainage of several blocks of 8, 10, and 12 houses, through 4-inch pipes where the inclination was good, that is to say, 1 in 30 to 1 in 60.

What quantity of water and of rain respectively formed the basis of your calculations?—100 gallons per house water-supply, and two inches of rain on the total area occupied by houses, yards, and gardens; the

[Mr. Grant. combined quantity to be discharged by house-drains in two hours; for example:—

20 houses occupying an area of .	10,000	square feet.
Two inches rain on this . .	1,666	cubic feet.
20 houses supplied with 16 cub. ft. each	320	
	2)1986	cub. ft. discharged in 2 hours.
	60) 993	cub. ft. in 1 hour.
	16·55	cub. ft. per min.

A 4-inch drain laid at an inclination of 1 in 50 would discharge double the large quantity allowed in the above case for 20 houses; or, in other words, discharge 2 inches of rain and the daily supply of water in one hour.

What may be the proportion which the drainage from the interior of the house and the rainfall allowed for in your calculations bear to each other?—This varies with the number of houses per acre, but in a large district the quantity of rain calculated upon as likely to fall and be discharged in 24 hours was 15 times the amount of house drainage.

You were directed by the Works Committee to report on the means of the combination of the water supply with the house and general drainage works for the complete drainage and cleansing of a block of houses comprising the fever-nest known as Jacob's-island, Bermondsey? —I was.

What was the extent of the block of buildings you so laid down?—The total area was about 50 acres, the area built upon about 41½. The number of dwelling-houses, 1317; of granaries, manufactories, and buildings other than dwelling-houses, about 50 more; the average number of houses per acre being 32.

Will you state the sizes of house-drain branches and main or trunk drains you propose?—The house branches to closets are 4 inches diameter; to sinks 2 and 3 inches; the main lines are 6, 9, 12, 15, and 24 inches.

How many principal mains are there, and what are their sizes at the outlet?—There are four main drains; one measures at the outlet 24 inches diameter, to take the drainage of about 23 acres and 630 houses, besides making allowance for 10 acres and 670 houses more, which may be added at a future time. A second main line is 15 inches diameter at the outlet, to take the drainage of 10 acres and 364 houses, besides providing for 255 houses which may be added at a future time. The third main line is 9 inches, to drain 3¼ acres and 162 houses, besides providing for three-quarters of an acre and 107 houses more which may be added. The fourth is 12 inches at the outlet, to drain 6 acres and 177 houses, besides half an acre and 140 houses more which may be added at a future time. Provision is made for still further, if required, concentrating the streams of drainage into one line.

Supposing that you had an order of Court for the execution of this combined work of water-supply and drainage, within what time do you consider it might be executed?—From three to four months.

How much of the Surrey and Kent district might be with safety similarly drained in blocks separately, with the aid of the general and subterranean surveys ?—All the more densely-built and most necessitous part might be similarly drained into the best of the existing sewers which surround the blocks. The outlets could be afterwards connected, and concentrated in the direction most desirable. Mr. Grant.

In this part of Bermondsey have you found many house-drains constructed under the former Surrey and Kent Commission ?—Most of the houses drain into cesspools, but there are a few drains connected with the sewers in Great George-street and one or two other streets.

What was the size of house-drains made most recently before the late Surrey and Kent Commission ?—9 and 12 inch brick barrel-drains; about three or four years ago 15 inches; and if to more than three houses, 18 inches.

What is the area of friction of these drains ?—If they were full, the area of friction would be, in 9-inch drains 2·356 feet; 12-inch drains, 3·1416 feet; 15-inch drains, 3·927 feet; 18-inch drains, 4·712 feet; but inasmuch as the stream of drainage from a house of any size will never fill the whole area of even the smallest of these drains, the actual frictional area varies with the quantity of water passing through them.

What is the frictional area of the tubular drain you provide for a house ?—In a 4-inch, if full, 1·047 feet, or one-third that of a 12-inch drain.

Supposing you were to drain from the back instead of the front, what difference would it make in the length of the house-drains ?—It varies; but the average of many blocks in different localities may be stated in round numbers to be by front drainage *more than twice* the length of drain that is required by back drainage; in some cases it is three times.

Then if the frictional area of a 12-inch brick barrel-drain is three times that of a 4-inch pipe, and the length is double, the total frictional area of the one must be very greatly in excess of the other ?—About six times in the case supposed.

Would it not be only in case of difficulties as to property that you would drain from the front instead of the back ?—Only in such cases. For instance, in the Bermondsey block there are 21 houses which must be drained separately, as the mill-stream is immediately under and at the back of them; but, excluding these, there is but one house in a hundred through which a drain would need to be laid.

Is there the same disproportion in the size of the main sewers formerly made and those you have laid and recommended in different places ?—There is.

What are the sectional areas of the main-lines you have proposed and those which exist in similar streets ?—The sectional area of the 12-inch main pipes is ·7854 foot; of the 15-inch ·98175; the area of a very common size of sewer in similar streets (a sewer 5 feet high by 3 feet wide, semicircular top and bottom) is 13·07, or from 13 to 17 times the sectional area of the pipe-sewers.

Supposing the portion of Bermondsey formerly referred to were to have complete house-drainage as well as main-drainage on the plan which was formerly recognised, what would be the proportional frictional area ?—Probably four to six times that of the system proposed.

And a proportional excess of water to keep the drains clear ?—Yes, more.

Mr. Grant. What the difference of cost?—This is difficult to ascertain precisely, but the averages of several blocks carefully calculated are from six to ten times that of the tubular back drainage.

What is the actual amount of deposit in the cesspools and such sewers as there are in the district?—There are in 648 cesspools about 30,000 cubic feet of soil, besides that in the sewers, which is very great, but constantly varying.

What difference of fall in the house-drains may there be by back and front drainage?—Never less than double in one case of the fall in the other, and generally much more.

What advantage in point of fall in a flat district like the one in question does the use of tubular sewers give you over the main lines of brick sewers?—In the one case a fall of from 9 to 10 feet has been obtained in about half a mile, whereas with brick sewers this would have been reduced to 5 or 6.

Suppose that it had been required to keep such drains and sewers in good action under the former plan of drainage, by what amount of water or arrangement of water could it have been effected?—I do not see any mode of keeping clean by any self-acting process such large sizes of drains and sewers, especially in a flat district.

You have doubtless observed cases where water carrying soil or detritus in suspension down proper inclinations was arrested by the closing of the outfall, as in the case of the old Surrey Commission sewers, which are below high-water mark during the high tides?—This is an inevitable and universal consequence in the Surrey and Kent or any similarly situated district drained on the intermittent system.

Such water when so arrested of course deposits the matter in suspension?—It does.

Now, when the surface sewer-water so arrested and detained during high-water (upon the intermittent system of drainage in Surrey) is discharged by the opening of the sluices at low water, does it lift and remove all the matter so deposited?—No: only that which is held in suspension.

The surface sewage-water is then merely decanted off by the opening of the sluices?—Exactly so. The grosser matter has to be removed either by hand labour alone, or in combination with large bodies of water flushed out.

What, from your own experience and observation in this district, do you consider the effect of ponding up the sewage by the intermittent system of drainage?—1. That it requires that storage room should be provided not only for the ordinary amount of sewage collected during the six or seven hours that the outlets are closed, but for the extraordinary falls of rain which sometimes occur during high water. 2. This storage room is obtained in the most expensive manner by making prolonged reservoirs, thereby making the most extravagant use of materials. 3. That the sewage, instead of being got rid of from every house and street as rapidly as it is generated, is retained to the detriment of health and comfort. 4. That during this detention the grosser particles are deposited and accumulate at such a rate as to require constant manual labour for the expulsion of the deposit. 5. That the discharge into the river can take place only at the most objectionable time, namely, at or near low water, when the return of the tide carries the sewage up the river instead of carrying it away. 6. That the limited fall is made still

less by the necessarily large size of the sewers, and the great length to which such main lines must extend. 7. That the sewers require expensive adjuncts in the shape of side-entrances, flushing and ventilating gratings, the cost of which, added to the constant expense of cleansing, makes it a very expensive mode of drainage. [Mr. Grant.]

What is the nature of the inclinations of the present main lines of sewer in the Surrey and Kent district?—In many cases they are on a dead level for considerable lengths. An inclination of about 3 feet per mile may be taken as an average on the main lines. The fall is so trifling that the flushing-men are in the habit of turning the water in either direction in some of the sewers.

Of course such inclinations are quite inconsistent with a proper discharge of the sewage?—They are; even if the outlets were constantly open the sewage would not pass off with sufficient speed to prevent deposit.

What upon this intermittent system of drainage would be the additional quantity of water required to raise and carry away all the matter deposited during the interruption of the first flow from the house-drains, and from the branch pipe-sewers which drain blocks of houses?—No additional quantity has been found to do so by any natural or self-acting process. More or less manual labour, according to the inclinations and other circumstances, has to be employed in conjunction with the force of water, to keep such sewers at all in working order.

The additional supply of water required in the intermittent or sewer reservoir system of drainage must be sent in by pumping, or derived from reservoirs or new water-works?—By one or other of these means.

It follows, then, from the facts observed—does it not?—that by pumping at the lower level, so as to lift the sewer water and continue the flow, less water and less pumping will be required than will be necessary at the upper end and on the intermittent system of drainage, and to remove the matter deposited in consequence of the interruption of the flow?—It does.

It is then only a question of a larger or smaller amount of pumping?—Precisely so in the case assumed.

And the least demand for water would be by a tubular system with direct pumping?—It would; with the additional advantage of continuous flow.

If the house-drains keep quite clear, the junctions, *à priori*, will keep themselves clear?—Yes; a very important point to be attended to in laying out drainage is to unite the streams and concentrate their flow as much as possible.

Then, as far as house-drains are concerned, can you contemplate the want of any additional supplies of water to keep them clean?—With a complete tubular system of drainage, I believe the present supply, properly delivered and distributed, to be sufficient for drainage purposes.

According to all your experience, any system of house-drains, union branches, or trunk-sewers, that collects the deposit, is faulty in construction?—Yes; the processes of flushing or cleansing and ventilation are the necessary attendants only of a faulty system of drainage.

At present there is constantly a large amount of evaporating surface of decomposing refuse in the block before referred to?—There is; many of the cesspools are close to and immediately under the houses. Some of the houses are built over the filthy tidal stream, and others close to stagnant ditches of the most offensive character.

Mr. Grant.

It is stated that the block of houses at Westminster already drained with pipes keep themselves clean; thus where this plan is adopted in connection with a supply of water no matter of course remains to decompose?—It passes off immediately it is generated.

You examined, some months ago, the drainage of the Cloisters of Westminster Abbey, by order of the late Metropolitan Commissioners of Sewers: what was the result of your examination?—I examined every inlet on the surface, whether closet, sink, or rain-water pipe, and examined the outlets into the main sewers under; and I found them all perfect. The pipes at the outlet were as clean as when first put in some seven or eight months before.

And that would be provided with probably one-third the water now supplied?—I believe so. There was a large tank, from which one length of the pipes could be flushed at pleasure; but it did not seem ever to have been required, the water ordinarily coming from the houses being sufficient to keep the drains always clean.

Were the residents in the Cloisters satisfied as to the efficiency of the drains?—Most perfectly so. The Very Rev. the Dean and the occupants of every house expressed themselves pleased with the improvement the new drainage had effected.

Whilst under a system of constant supply of water, combined with a system of tubular back drainage, there would be the saving of probably half the water now used;—you were directed to estimate from survey what would be the saving in constructing the drainage adapted for thus economising of power and water; distinguishing from the cost of back tubular drains the expense of tubular drains through each house into the street; and also setting forth the cost of brick drains and sewers on the system pursued previous to the investigation of the Metropolitan Sanitary Commission; stating also the frictional area of each?—I was.

You have made these by measurement, &c., on the plans?—Yes.

Give in the plans from which you estimated the comparative cost of back and front drainage and water supply?—The plans were made chiefly to show by comparison the relative merits of back and front drainage, but they as clearly illustrate the economy of laying the water-pipes at the back instead of through each house.

State the comparative results of the several blocks?—

In one block of 44 houses,—

- The length of drains by back drainage was 1544 feet.
- Length by separate drainage, feet.
- Cost (exclusive of pans, traps, and water in both cases) of back drainage, 83*l.* 12*s.*, or 1*l.* 18*s.* per house.
- Cost of separate tubular drainage, 467*l.* 9*s.* 6*d.*, or 10*l.* 12*s.* 6*d.* per house.
- Cost of separate brick drains, 910*l.* 19*s.*, or 20*l.* 14*s.* 1*d.* per house.

In another block of 23 houses,—

- The length of back drains was 783 feet.
- Of separate drains, 1437 feet.
- The cost of back tubular drains, 45*l.* 12*s.* 6*d.*, or 1*l.* 19*s.* 8*d.* per house.
- Of separate tubular drains, 131*l.* 13*s.* 6*d.*, or 5*l.* 14*s.* 6*d.* per house.
- Of separate brick drains, 305*l.* 7*s.*, or 13*l.* 5*s.* 6*d.* per house.

Mr. Grant.

In another block of 46 houses,—

The length of back drainage 1143 feet.

Ditto by separate ditto, 1892 feet.

The cost of back tubular drainage, 66*l.* 5*s.* 2*d.*, or 1*l.* 8*s.* $9\frac{3}{4}$*d.* per house.

Ditto of separate ditto ditto, 178*l.* 19*s.* 8*d.*, or 3*l.* 17*s.* 10*d.* per house.

Ditto of separate brick ditto, 390*l.* 4*s.*, or 8*l.* 9*s.* 8*d.* per house.

In a fourth block of 46 houses,—

The length of back drains 985 feet.

Ditto of separate ditto, 2913 feet.

Cost of back tubular drainage, 66*l.* 8*s.* 2*d.*, or 1*l.* 8*s.* $10\frac{1}{2}$*d.* per house.

Ditto of separate ditto ditto, 262*l.* 11*s.* 7*d.*, or 5*l.* 14*s.* 2*d.* per house.

Ditto of separate brick ditto, 614*l.* 16*s.* 3*d.*, or 13*l.* 7*s.* $3\frac{3}{4}$*d.* per house.

Have you made arrangements for subsoil drainage as well as for relieving the surface of its water?—Yes.

Will you describe the nature of that arrangement?—It is simply to lay agricultural tiles, varying in size from $1\frac{1}{4}$ to 4 inches, immediately under the other drains, in some cases over; and draining into the existing large brick sewers.

What would be the additional expense per house of this?—The cost averages 4*s.* 2*d.* per house in Bermondsey, and 4*s.* $4\frac{1}{2}$*d.* per house in another large block.

What would be the expense per house of water-supply, drainage, and subsoil drainage?—These, including a dust-bin to each house and new closets where required, average 6*l.* 15*s.* per house; to pay off the principal and interest of which in thirty years would require 8*s.* per annum, or $1\frac{3}{4}$*d.* per week.

Have you a good outfall for this block?—The best existing outfall is the main Duffield sewer, 5 feet in diameter, the invert of which is about 3 feet above the level of low water.

What size would the whole drainage area be?—About 350 acres might conveniently at a future time drain into the same point.

Then this block being formed, you can lead either to a lower artificial outfall than is at present provided, or to an overflow, which may be selected?—Yes, to either.

And this process may be carried out irrespective of any plan of drainage as to the main outfall?—It may be carried out at once without waiting for the settlement of that question.

Do you consider the present a sufficient and permanent outfall?—No, but as the best available.

Then you consider that it is important to determine, as soon as possible, upon a better outfall, but that the drainage of these wretched districts may in the mean time be laid and their condition improved without delay?—Certainly.

Are there not many such districts in which this might be done?—Yes; many.

What is chiefly the class of houses here?—About one-half of the whole number do not exceed 15*l.* per annum, and only 71 out of 1317 exceed 25*l.*

With one-third the length of pipes by back-drainage, will there not, on account of the increased force of the water, be less than one-third the chances of stoppages, consequently less than one-third of the annoyances from the intrusion of workmen to open drains?—There will.

Mr. Grant.

With regard to the objection which has been made to back-drainage, that, in case of stoppages in the house-drains, one tenant suffering annoyance is at the mercy of another on whose premises the obstacle may exist, although it may not inconvenience the latter, do you believe it possible to avoid this difficulty?—Yes; if the Commissioners of Sewers took entire control over house-drains as well as mains, I have no doubt they would find respectable persons who would contract to keep in working order the house-drains of a district for 6*d*. per house per annum.

Have you in the course of your ordinary duties, examining into complaints of imperfect drainage, frequent complaints of bad smells from house-drains passing under the floors?—Very frequently, as well as of the damp created.

Is it not a common remark of the complainants that these smells are worst "when the water is on," or "on water-days?"—It is.

What is the cost of flushing the old system of sewers?—This varies very much in different districts, being highest in the Surrey and Kent district. As far as I can approximately ascertain it, it amounts to about 2*s*. 3*d*. to 2*s*. 6*d*. per house per annum in the Surrey and Kent district, that is, including wages and works necessary for such purposes. This, however, would be most materially increased if the same system of brick sewers were extended into every street. The many houses which do not communicate with the present sewers reduce the average cost of flushing per house for the smaller number which do communicate.

What are the expenses other than wages?—The cost of flushing-gates, penstocks, side-entrances, ventilating gratings, and the cost of digging down to and breaking holes into the sewers at frequent intervals, where there are no side-entrances or casting-holes, and making good such breaches.

Were not attempts made to ventilate one of the sewers last summer, and what was the result?—Several attempts have been made, the last by means of the steam-jet, and also by passing the air of the sewer through a furnace into a factory-chimney. The steam-jet will ventilate a certain length of sewer, if it be ever so foul; and, for a special purpose, might be a useful means of preventing danger. By the factory-chimney there was a constant and sensible draught kept up, which would, I believe, justify the cost of making a connection with such of the present main sewers as were near tall chimneys, at least as a supplementary means of ventilation.

Would not the connexion of the rain-water pipes of houses be effective in ventilating the sewers?—Yes; I have connected them in a few cases where their heads were not close to or under bedroom windows.

Have you provided means of ventilation for the tubular systems laid out by you?—No; I believe ventilation, flushing, and additional supplies of water to be necessary only for an imperfect system of drainage, and that the cost of them would go far towards executing a complete and perfect system of drainage.

A block of houses at New Peckham has been referred to as a case which required periodical flushing. Can you state the conditions under which the drains were laid down and put in action?—The drains were put in by the owner very imperfectly, and without water to each closet, but with a flushing-tank to be used occasionally. One of the branch lines, more imperfectly laid than the others, got deranged, but the main line remained clear and in action.

Have you also had occasion to examine the existing water-supply?—Yes; the district referred to is chiefly supplied by the Southwark and Vauxhall Water Company. Mr. Grainger.

It appears to be admitted by the engineer of that Company that not above a third of the water pumped in is used, and that full two-thirds are wasted?—Mr. Quick has expressed a similar opinion to me, and I have no doubt, from my own observation, of its accuracy.

He also stated that, from the nature of the supply (being intermittent) and from the construction of the drains, accumulations take place, the drains become choked, and the water runs over; does that agree with your observation?—It does. From imperfect pipes and ball-cocks, and stand-pipes for courts without cocks, there is in the poorer districts more water wasted than is used; in fact, it is worse than wasted, for it is the cause of damp, dilapidation, disease, and injury wherever there is not perfect drainage to carry off the waste water.

Have you known of persons taking water for domestic supplies from ditches in your district?—In Bermondsey that is the case with 203 families, composed of 865 individuals, residing in 152 houses, chiefly in Jacob's Island and adjoining the mill-stream, which serves at once as an outlet for the drainage and the means of water supply.

Did the result of your inquiry from house to house show any difference in the amount of mortality during last summer among these 865 individuals and the other parts of the block where the inhabitants were supplied by the Water Company?—It showed an excess of 37 per cent. over the portion supplied by the Water Company.

Have you in other cases met with excessive mortality, which appeared due in any manner to the nature of the water used by the sufferers?—Yes; last summer, during the prevalence of cholera, I had occasion to report to the Metropolitan Commission of Sewers two remarkable cases of excessive mortality which were in my opinion clearly traceable to the contaminated water used by the inhabitants.

What were the circumstances in the first case?—The first case was that of a court called Surrey-buildings, Thomas-street, Horsleydown, consisting of 13 houses, the backs of which were towards Truscott's-court, of similar character and extent. In Surrey-buildings nine or ten persons died of cholera in five days, and in Truscott's-court not one. In the first court the people were supplied with water from a well on a level with the pavement, from which foul water drained into and polluted it; the other was supplied with pure water. This was the only point in which the two courts differed, namely, the water-supply; and whilst in one court one or two individuals died in every second house, in the other the inhabitants remained safe.

What was the other case you referred to?—That of Albion-terrace, Wandsworth-road, which consisted of 17 houses of a superior class, in which some 25 to 30 persons died in the course of 10 days. This terrace was supplied by a spring which passed through imperfect pipes and tanks close to cesspools and drains. The water got contaminated after a heavy storm of rain in July, and this frightful mortality occurred among persons in easy circumstances, whilst the population east and west of this terrace were not attacked. The water-pipes served the houses from No. 1 to No. 17 inclusive, and these were the exact limits of the ravages of the disease.

Mr. Grant.

In the Bermondsey block what proportion of the houses are supplied by the Water Company and from other sources?—Of 1317 houses, 1066 are supplied by the company directly, and 35 more by stand-pipes used in common; 152 by the filthy mill-stream, 56 by pumps, and 8 are without any means.

What is the average charge per house for water?—About 13*s.* 9*d.*, or rather more than 3*d.* a-week per house.

How many public-houses may there be in the block?—18, or 1 for every 72½ houses.

Are the houses damp or water-logged?—There are many in Wellington street and Rose-court which have water standing under the floor and sometimes over it. The occupants pump it out when it gets over the floor.

Where do the tanners and other manufacturers get their supply of water from?—Some from the tidal stream, and others partly from the Water Company.

Has the character of the water in the mill-stream and ditches in the neighbourhood at all changed of late years?—It has of late years become much polluted from the increase of houses, the drainage of which falls into these ditches. Some seven or eight years ago hardly any of the houses were supplied by the Water Company; but about four years ago a great many of the landlords had water laid on to their properties.

What is the amount of poor's rate collected in the parish?—This year it is 3*s.* 2*d.* in the pound, and I believe amounts to about 18,000*l.*

What other rates are paid?—

	s.	*d.*	
Improvement rate for lighting, paving, and scavenging . . .	1	6	in the pound.
Sewers-rate	0	8	
Church-rate, about . . .	0	2	
Poor-rate (as before) . . .	3	2	
Total, about . .	5	6	

The water-charge adds about 10*d.* more.

What is the distance between fire-plugs?—From 60 to 80 yards.

How often are the inhabitants supplied with water?—For a portion of every day excepting Sundays.

Could the polluted mill-stream be entirely got rid of at present?—Apart from the opposition offered by the reputed owner to any interference with it, the stream could not be filled in until other means of drainage were provided.

Could it be got rid of if these works were executed?—It could be either filled up or kept constantly cleansed; the inhabitants would no longer be dependent on it for either water or drainage.

Have you met with instances of families being indebted to public-houses for their supply of water?—I have, in Bermondsey; also in another district in the neighbourhood of Old Kent-road; and in a number of houses at Battersea-fields. This practice was till lately much more common than it is at present; the publicans in poor districts paid a very high water-rate to the Company, owing to the large quantity used by them in the practice of selling about a thimbleful of gin and a pail of water for a halfpenny. The practice is by no means extinct now.

Mr. Grant.

Have you not estimates for carrying a supply of water into each house?—Yes; a constant supply into each house and closet in the district.

By what means, and at what cost?—By a tank elevated at a height of 35 to 40 feet, and at a cost to each house for the tank of 13*s.*, for the pipes, &c., 29*s.* Total average per house, 42*s.*

Are you aware of any houses in that neighbourhood already supplied on the constant system?—Yes; there is a small block of eight or ten houses in Rose-court which are supplied by one tank, and have a tap in each house. The tenants expressed themselves to me highly pleased with it.

Do you think the same advantage would follow over the whole district?—It would, as a matter of course.

What, according to your estimate, would be the expense of service-pipes for carrying in water for a constant supply?—I have already given the estimated cost of the apparatus for water supply in one block; in another, the average cost per house is, for the tank, 17*s.*; for the pipes and cocks, 26*s.*: total, 43*s.* per house. In another, 50*s.*, including tank, which would, however, supply as many more houses, and reduce the cost to 37*s.* 6*d.* per house. In another, it amounts to 30*s.* 6*d.* per house, including tank, which only amounts to 7*s.* 6*d.* per house total cost. In another case, where the whole of the pipes, mains and branches, would require to be laid, there being none at present, and where, from its peculiar situation, a constant supply may be given without a tank, the total cost would be 45*s.* per house. This, however, includes a large number of stables and several workshops attached to the dwelling-houses. All these estimates are made at prices for which a single house may be at present done.

Besides the expense, will there not be the objection to the mode of delivery by tank resulting from the consequent exposure of the water?—The tank would be covered, and the water constantly changing. But if the general supply of water were constant, or the Water Company would consent to supply this district on the constant principle, the tank would not be required, and its cost—850*l.*, or 13*s.* a house—might be saved.

Then the cost of this tank is to be incurred with the view of not delaying the question of drainage till the settlement of the question as to a general system of constant water supply?—Entirely with that view.

But still the air would not be excluded from the tank?—It would not.

If you had to put a separate tank to each of all these houses, what would be the expense?—To afford the same advantages, about four times as much.

What size of mains are proposed for these houses?—There is already a main water-pipe in every street. Their size varies from 3 to 12 inches.

What size would the tank be?—It would hold 3000 cubic feet, or $1\frac{1}{2}$ cubic feet to each house. But the supply would be rendered constant and unlimited; the tank acting as a standpipe and reservoir in case of repairs being required to the main pipes.

How many houses would that supply?—1317 in the first instance, and more eventually if required.

Apart from the expense of the tank, what would be the expense per house for water apparatus?—Twenty-nine shillings.

Mr. Grant.

It is presumed that you give your estimates at such prices as you believe the contracts might now be obtained for?—I have in everything, both for labour and materials, allowed the present prices given for small works, and would undertake to get twenty respectable men of capital to undertake the execution of the works in the most complete manner for the estimated cost, and that without competition.

You stated a saving in length by back drainage, apart from its other advantages, to be at least one-half. What would be the saving of supplying water *de novo* at the back?—The saving in length would be about the same, and the cost of laying the pipes from the front would, on an average, be fully double the cost required to take them at the back; in many cases more.

Would there not be a probable gain to the tenant if the water-pipes were laid under the same contract with the drains?—The same trench would serve in most cases for both, and thereby cause a saving as well as in the cost of relaying the paving.

Besides the Bermondsey block of drainage you have laid out water-supplies and drainage at the back in other blocks?—Yes, in four or five other blocks.

In what proportion of cases in these other blocks did you find it necessary to carry water distributary apparatus and drains through the houses?—In one case of 51 houses, another of 226 houses, and a third of 270, there was not one house in which the water-pipes or drains had to be carried through the house. In a small block of 35 houses 2 houses would be passed through. In another of 124 houses, the piping would be carried through 4 houses.

For all these results, then, for an improved domestic water supply, and for an improved mode of cleansing, you calculate that not only could no additional supply of water be wanted, but that scarcely one-half would be wanted?—On a better system one-half the quantity at present supplied to each house by the Southwark and Vauxhall Water Company would amply serve for the domestic supply and keeping clean a proper system of tubular drainage. *At present that company pumps into the district a quantity considerably more than equal to* 100 *gallons daily to each house, and the total rainfall upon the area, united.*

From the disuse of separate ball-cocks and tanks, is there any doubt that the quality of the water would be greatly improved?—I have no doubt of it.

Supposing the water to be delivered cool, would there not be less decomposition in the matter carried away?—There would; but with a perfect system of drainage there would be no time given for the process of decomposition to take place, at least upon the premises.

Since the plans have been carried out at the Cloisters of Westminster, is it not stated that there have been no smells from the drains?—Such was the result of my examination made from house to house; and also that fever, which had previously prevailed, had ceased.

Can you tell what the present water-rent is additional per house, and over the whole district of which you have formerly spoken?—The total revenue is 763*l.* 12*s.* 6*d.*, being about 4½ per cent. of the gross rental. The annual charge is 3*s.* 6*d.* per room, with a deduction to a landlord farming it of 20 per cent.

Do you find this about the average water-rate in other parts of your

district?—In several districts which I have carefully examined, the water-rate varies from 4½ to 5½ per cent. on the gross rental. Mr. Grant.

Do you not consider it equally desirable, for the sake of the tenant as well as for the care of the general apparatus, that the service-pipes should be under one and the same inspection?—I do. The chief obstacle, I believe, to the water companies giving a constant supply of water is, that at present there is no security for the soundness of the supply-pipes and water-cocks; and the waste consequent upon this obliges them to shut off one part of the district whilst they are supplying another.

Would it be practicable not only to get this done, but also to get it kept in order for a certain number of years?—Perfectly practicable.

Would it not be practicable to have the main drains and water-pipes looked after by the same person who superintended the water?—It would.

Will you look to this examination of W. C. Mylne, Esq.?—

[Extract from the Examination of *W. C. Mylne*, Esq., C.E.]

"Were you consulted as an engineer on a plan for supplying Paris with water?—Yes, I was, in 1817 and in 1823: I am still engaged upon that subject.

"In the plan you have proposed, did it not form a part that the tenant's communication-pipes should be provided and laid down by the company as an essential part of the works of distribution?—Yes, I considered it the most desirable that it should do so.

"Will you state the advantages to the tenant or the public that were proposed from that part of the plans over the common method, leaving every uninformed occupier or owner to the necessity of employing a separate plumber to complete as he might that part of the general machinery?—In the first place, it would effect a considerable saving of capital; in the next place, it would be done on principle and in a superior manner. The trading plumber has no motive to carry out improvements, two lengths of pipe may be put where one would serve. As an example of the improvement proposed to be introduced in detail, I had intended to introduce lead pipes, with screw-joints, similar to those used in wrought-iron pipes. The cost of these joints was not above 1*d.*; they would have superseded completely the plumber's joint; and neither the plumber, nor his irons, fire, ladle, nor labour were necessary, and an expense of 1*s.* 6*d.* per joint was saved. In various respects we should have economised the machinery for distribution.

"This portion of the machinery being laid down by the company, was it proposed to charge at once the expense of this outlay upon the owners or occupiers, or to charge for it a rental?—It was proposed to charge interest on the extra amount of outlay as a rental.

"Then these tenants' communication-pipes would have been under the same general care as the mains or iron pipes of distribution?—Yes, that was my view; and my opinion has always been that, as public traders, that which is best for the public customer is ultimately the best for the company by whom they are supplied.

"What would be the extent of probable advantage to the public in respect to the saving of repairs?—Very great: one public officer would have been appointed to attend to the laying on of all houses, as also to all the repairs. Under ordinary circumstances, when an accident occurs within or without the building, the tenant has to think how it will be repaired, and has to consider how he is to pay for it, and who is to be sent for; the plumber, when he arrives, makes his repairs in his own way, which is without reference to any general system. Two-thirds of the labour, on the occurrence of any accident, is in the journeys, which would be rendered unnecessary under a general system, by which, on such an occurrence, the

Mr. Grant. inconvenience may be remedied at once. The advantage of having the tenants' communication-pipes placed under one general system would have been, that they would have been so laid down at first as to have avoided many of the incidental injuries which they are liable to from frost and accidental circumstances, as well as being placed where they could readily be repaired.

"In the case of a company undertaking to lay down these pipes, would not the repair of them form part of the general charge, and be added to the rent?—Yes; frequently an accident occurs towards the end of the tenant's term of occupation in the premises, and the cost of repairing it may be equal to his quarter's rent. Being a tenant at will, or near the termination of his lease, he says, 'I may be turned out shortly; it is not worth my while to undertake it;' and it is left undone if within his premises.

"Increased dilapidation must be the consequence?—Of course: that naturally results.

"In that plan, then, you assumed as a principle that the tenants must be relieved of the immediate outlay, and the expense be spread over a period and collected as a rent?—Yes, certainly. This was the more necessary at Paris, where the dwellings are extensively occupied in flats (as at Edinburgh and Glasgow, and in several other towns) as distinct tenements. Each flat would be held for various periods, some of the nature of tenancies at will, some of them of the nature of leasehold, and under every description of interest and period of occupation. Of course, the parties having short intervals would not undertake the immediate expense of the outlay for the permanent improvement, nor would the persons in the lower apartments pay for the repairs in any lower part of the building necessary for the supply of any upper apartment.

"Did the plan of comprehending the tenants' communication-pipes and the whole machinery under one general system offer any advantages in respect to economy and sufficiency in laying down the iron pipes?—In a new town there would often be much public economy in laying pipes on both sides instead of in the centre of the streets: there would be the saving of lead pipes, the saving of repairs to these lead pipes, the avoidance of the inconvenience and expense of breaking up the roads for that purpose, the saving of the inconvenience to the tenants in the event of frosts, from there being less of their smaller pipes exposed. In a street of 60 feet wide the saving of lead pipe would be about 20 feet in each tenant; that is, if the street is built upon each side there would be 40 feet of leaden pipe saved in a house frontage of (say) 20 feet; therefore 20 feet of iron extra would avoid the use of 40 feet of lead.

"In carrying the water up the higher houses, would you not have introduced iron pipes?—We should have introduced iron wherever we could. At that time, when lead was very dear, I contemplated the use of tinned copper pipes."

Will you state whether you agree with him as regards economy to the tenant?—I do.

In laying down house-drains, what proportion of the expense does the cost of pipes bear to the other outlay?—The cost of pipes is at present about one-half of the whole.

Do you agree that, as has been stated, the pipes for the supply of water should be laid lower than at present, for the sake of coolness and preserving the water at a middling temperature?—I do. It is a point of great importance, which has not always been attended to.

Does it appear to you that the water can be carried into the premises of the poorer description of tenements, or indeed of any class, by service-pipes on the constant system of supply, and carried away from them by waste or drain pipes, if the work is to be dependent on the separate

efforts of individual householders, or by requiring immediate outlays, or by any other system than by common contracts and repayment by annual instalments of principal and interest over periods of time?—It does not; the most stringent legislative enactment would never effect these improvements if the cost were to be paid in one sum. It would, in many cases, be most unjust; but it is, in the majority, a simple impossibility. Mr. Grant.

From your interviews with owners and occupiers, do you doubt the practicability of carrying out improved works of water-supply, drainage, and cleansing by means of distributive charges?—I do not; so far from its being impracticable, and considered so by owners or occupiers of houses, one instance will suffice to show. At the present time I am in communication with two parties in the district, large proprietors of house property, who are anxious to carry out works of improved drainage, but who will not undertake them if they are to pay down the cost of these works in one sum; but, if the charges are distributed over a period of years, they would at once, and cheerfully, carry them out.

With respect to the purity of the river water, under what circumstances could the sewage pass into the Thames with the least amount of pollution to its waters near the metropolis?—At high water, when it would be permanently removed below the point of discharge a distance equal to the difference of ebb and flow.

If discharged at low water, at what distance below the metropolis must the outlet be to prevent the sewage being sent into the metropolis?—A distance at least equal to the space traversed by the flood-tide: probably from 7 to 10 miles below the lowest part of the metropolis.

What proportion of the Surrey and Kent district is under Trinity high-water mark?—About 9 out of 27 square miles.

The low-lying part embraces the oldest and most densely-built portion?—It does.

With sewers 5 feet in height, having outlets at the level of low-water mark, what is the greatest amount of fall which can be obtained in this flat district?—The crown of the sewer being at least 4 feet under the surface of the ground, where on a level with high-water mark, the fall would be about 9 feet, which, if divided over 3 miles, would give 3 feet per mile.

When heavy rains fall, do the present main sewers carry them off during the five or six hours that the outlets can be kept open?—No; it takes four or five days, or from eight to ten tides, to reduce the run of water in the Duffield to its ordinary amount after a heavy fall of rain.

Is there not a vast amount of animal matter passes through the sewers?—Yes. After the Friar-street was cleansed, large masses, like bolsters, of the entrails of horses and sheep, clotted together and in a state of putrefaction, were sent into the Thames. These were the refuse of the knackers' yards, catgut manufactories, and slaughter-houses.

What is the distance between the conduit-pipe of the South Lambeth Water-works and the outlet of the nearest sewer?—The conduit-pipe, by which their well is supplied from the Thames at all states of the tide, is immediately below the south end of Hungerford Bridge; and the outlet of one of the large sewers is close to the south end of Waterloo Bridge. The distance between is about 200 yards.

Mr. Cresy, jun.

Mr. E. Cresy, Jun., examined.

Are you not Assistant-surveyor in the Sewers' Office?—Yes,

Were you not instructed by the Works Committee of the Sewers' Commission to examine the house-drains of a block of houses at Hanway-yard?—I had the honour to be nominated by minute of Committee, in September last.

Was not that block of houses characterized from the houses being placed more back to back than usual, and their having no back yards? —The annexed very beautiful and correct detailed plan of the locality in question, prepared by Assistant-surveyor Smith, exhibits in the best manner the nature of the distribution of the houses, and their situation with respect to each other; those in Hanway-street may be specially cited as instances of this very pernicious custom.

Did not the Committee propose the abolition of cesspools, and the substitution of a soil-pan apparatus?—I was particularly instructed by the Committee to report upon these points, and indeed no system of house drainage can be considered at all complete which does not include these requisites.

What was the amount of evaporative surface of the cesspools and house-drains you found upon the spot?—From the crowded nature of site it was particularly difficult to discover the situation and extent of these receptacles, otherwise than by that unerring guide the sense of smell; in many cases when the premises were characterized by a powerful effluvia, the inhabitants avowed their ignorance of the existence of any cesspool, and assured me, that if such were the case, it could not have been emptied for upwards of ten years. From a-house-to-house visitation made for the purpose of ascertaining the fact, I deduced an *approximate* extent of about 8,500 superficial feet or about ⅕th of an acre for the drains and cesspools over the whole area of nine acres, but in a long inhabited site of the kind under consideration, the whole soil becomes charged with decomposing animal matter, and for *in* sanitary purposes, presents an area of a considerably greater extent than can possibly be ascertained by the direct measurement of cesspools and drains.

Did you find it practicable to carry the drainage into the interior of this block of houses with the attainment of the advantages usually expected from back drainage?—The projected drainage shown on the plan by red lines, will best answer the question, especially if the eye be carried at the same time to the accompanying sections. The site, it may be observed, is peculiarly favourable for the development of the principles of sanitary engineering in their most extensive and complete application; the block forming a square island "insula," as the Romans would call it, with a good sewer running on each side, having sufficient fall, and at a most convenient depth. Although the instances of defective construction mentioned above are comparatively numerous, it will be remembered in how few instances it is necessary to take the lines of drainage under the houses, and with what facility the conveyance of the several house-drains is effected, so as to secure the greatest possible amount of acceleration to the flow; here the whole flow of the 282 houses is brought down to outlets, hence the amount must be nearly constant, and from the inclination given to the drains,

Mr. Cresy, jun.

a stoppage becomes next to impossible, provided always, that the inlets are properly trapped. In stating thus much with regard to the block under consideration, no personal credit is intended to be assumed, on the contrary, the whole of the excellencies cited are to be ascribed to the development of principle so perfect in itself, and so strictly in accordance with physical laws, as to ensure a certain amount of success, even in the hands of the unskilful, although capable of perfection, directly in proportion to the skill employed in its adaptation.

Of the work proposed, what proportion would the earth work bear to the rest?—About one-sixth of the total cost.

For the action of the soil-pans, it was proposed to carry the water to the interior of this block of houses, what would be the expense in earth work or otherwise, of laying down the water apparatus separately? —The advantages of united works under one superintendence are so numerous and so great, that considerable difficulty exists in accurately estimating the precise money amount, the sum of the two estimated separately, so much exceeds their value taken conjointly, as to cause the estimater frequently to discredit his own results. In every locality the ratio would vary. In the case of the property now under consideration, the mains are laid in all the streets; but supposing the *whole work* to be commenced *de novo*, we should have 7 yards cube to each house, and 3,154 yards to the mains; to which must be added 700 yards super. of paving, and a 10 per cent. for superintendence and contingencies, thus:—

		£.	s.	d.
282 houses at 7 yards each	1*s.* 1*d.*	106	18	6
Mains 3,154 yards at	1*s.* 1*d.*	170	16	10
700 yards sup. paving	1*s.* 6*d.*	52	10	10
		330	6	2
Add 10 per cent.		33	0	7
	Total	£ 363	6	9

Giving an *excess* of 363*l.* 6*s.* 9*d.* for the cost of mains, supplies, junctions, fittings, &c. may be taken as the same in either case.

What have you found to be the net gain by the combination of the two systems of works?—Hence we may consider that sum to represent the net gain by their combination.

Supposing them to be laid down and maintained in good action and repair for a term of years, what would be the expense of the complete distributory water apparatus, and of the house-drainage apparatus, and what would be the expense of the two combined, as compared with the existing expense of cleansing cesspools or keeping common house-drains in order, supposing the cesspools to be cleansed and the common drain to be kept properly in order?—I can but answer to these queries by putting in the estimates for the several works mentioned, subject to some observations, the whole question of estimates being here involved. Even in the most ordinary descriptions of work, great differences of opinion invariably are found among those skilful in the art of estimating, the value of raw materials, are constantly fluctuating; and although the average price of labour has not recently been subject to

Mr. Cresy, jun. much variation, *its* quality must now be taken into account, there being at the present time, as many descriptions of labour as there are of material. Hence, *one* of the sources of discrepancy, observable between several contractors' estimates for the same work. The prices given in the accompanying estimates, would by a small contractor, about to execute the works for a dozen houses, be considered quite unremunerative. One in a large way of business contracting for 560 or 1,000 houses, would probably estimate considerably below these figures. I have endeavoured to pursue a middle course, relying where they would serve me, on the schedules of the Commissioners, jobbing contractors, and for such items as are not therein contained, on my own former experience in private practice. The Board of Health would render an immense service to the science of sanitary engineering by collecting and publishing detailed estimates of as many executed works as possible, both in the metropolis and the towns under its jurisdiction, as well as the prices of materials, as drain-pipes, gas-pipe, &c. An efficient check would be established on the contractors, and far greater accuracy in the estimates would be attainable.

From what you know of the metropolis, would not this be as difficult a block of houses as could occur, for combining drainage and water supply under one and the same management?—Undoubtedly; a glance at the plan will demonstrate this. Nevertheless, the system of combined drainage will be seen to be perfectly practicable, the cases in which the lines pass under houses are very rare, and even there, but little inconvenience to the inhabitants would be occasioned, as the back premises would alone be traversed, and this would be more than compensated by the immense advantage of a combined flow.

When the inhabitants understood the nature of the object in view, do you think that any reasonable difficulty need be apprehended in their allowing an officer of the Commission to come to the back of the houses from time to time to clear obstructions, and keep the apparatus in good order?—Having inspected a number of these houses myself and conversed with the inmates, I am enabled to state that they are all perfectly sensible of the advantages to be derived from the proposed measures, and most desirous, that as little delay as possible should occur in putting them into execution. I may add, that in all the inspections I have made, every facility has been afforded me, and all opposition has vanished before an explanation of the nature and extent of my inquiry.

Might such a block as the Hanway-street block be drained irrespective of any question as to the general drainage of the metropolis?—Most unquestionably; the outfalls for that block are already provided by existing sewers, and the whole operation thereby involved is completely independent of all other considerations.

What have you observed to be the result of the system of laying down main lines irrespective of house-drainage and *vice versa*?—No practical general result can be obtained from so doing; the whole system must exist in the mind of the engineer as a whole, otherwise he pursues his course blindly, to his own discredit and the great pecuniary injury of his employer.

Supposing an order given to execute the work, within what time

could the same be completed?—If sufficient strength were employed to carry on the whole simultaneously, in from six weeks to two months. Mr. Cresy, jun.

What is your view of the practicability of carrying out the work by the system of compulsory orders served on the occupiers of the several premises?—I should imagine, from the experience I have had under the Commissioners as well as in private practice, that such a mode would be utterly impracticable. One man would be likely to begin, his next neighbour would demur; another would, as I have actually found to be the case, request to delay the works until he could communicate with his landlord in the West Indies.

If the drains are properly laid, would there be any accession soever for additional supplies for flushing purposes?—None whatever; the flow being constant, no deposit can possibly take place.

What will be the expense of the combined apparatus per house, under the old system, under the intermittent system, and under the constant system, respectively?—

—	Old system, brick-drains, and intermittent water supply.			Tubular drains, intermittent supply.			Constant supply by contract under Commission.		
	£.	s.	d.	£.	s.	d.	£.	s.	d.
House-drains and repairs . . .	6	7	0	3	4	7	1	19	8
Water-closet apparatus . . .	4	15	2	1	1	8	0	10	8
Kitchen sink	2	6	10	1	10	0	1	0	6
Yard drain	0	15	0	0	10	0	0	7	6
Water supply	7	19	2	4	19	1	0	19	3
Total . . £	22	3	2	11	5	4	4	17	7

This table exhibits the cost of draining, putting up water-closet apparatus, kitchen-sink yard-drain, and supplying water to a small house, under, 1st. The old system, with nine-inch brick-drains, lead cistern, Yorkshire stone sink, patent valve closet and its apparatus. 2nd. The modern system, with intermittent supply, slate cistern, stoneware sink, syphon-trapped closet, supposing the whole executed by a builder, for a single house. 3rd. The most economical plan, with the constant supply, requiring no cistern, and supposing a large number to be contracted for at once under the Metropolitan Commission.

In the Hanway-yard block what provision have you made for subsoil-drainage?—From that block being situated on comparatively high ground, with a good deep sewer in Oxford-street and Tottenham Court-road, carrying off all the upper drainage, it has been considered unnecessary to make any special provision for subsoil-drainage. In situations where this is required it is easily obtained by the use of pervious drain-tiles made of red earthenware and unglazed.

Within what period of time would any matter be completely removed from the site in question by the action of the drains you propose?—From the great acceleration of the flow induced by the concentrated back-drainage, I calculate that barely more than a minute would elapse, under ordinary circumstances, from the moment drainage matter enters the longest line till the moment it quits it.

Mr. Cresy, jun.

What district of the Metropolitan Commission is specially under your charge?—The eastern division of the Surrey and Kent district, comprising part of Bermondsey, Rotherhithe, Deptford, Greenwich, Camberwell, Peekham, Dulwich, Forest Hill, Sydenham, Lee and Lewisham.

Do you find in that district any of the water supplied to the houses to escape in waste?—A very large proportion; we have had no accurate gaugings taken, but noticing the time during which the water is on, the bore of the supply pipes, and the capacity of the cisterns and vessels provided for its reception, I should say that from two-fifths to one-half the quantity supplied is in many cases wasted.

What is the effect of this on the sites of habitations?—A most pernicious one; the wet soaks the whole of the soil, and has no means of escape, the subsoil being water-logged twice in twenty-four hours by the tide, and from the great portion of the district lying so remarkably low, it can only drain off for an hour before and an hour after low water.

Do you know of any other means of relieving this district than by pumping?—In the present state of science the engineer has generally the choice of several alternatives, but in this case he is so straightened as to have practically no choice at all. Either he must depress the outfall, which would be neither more nor less than lowering the bed of the Thames, or he must raise the district, burying the habitations one story, or he must have recourse to pumps. The whole Surrey and Kent district is, in fact, one vast "poldre," to use a Flemish term.

What do you find to be the expense incurred in removing by hand labour the deposit in the sewers after it has once been suffered to accumulate?—Under the Commission the cost varies with the nature and dimensions of the sewers from which it has been removed, but the book price for emptying and carting night-soil is 6*s.* 6*d.* per ton of 18 cubic feet.

Have you not in your experience found streets with a capacious sewer and few or no houses draining into it, and, on the other hand, house-drains laid down before any sewer is provided?—Frequently. I must acknowledge to have superintended such arrangements myself in private practice, although I fully confess the error of such a cause. But clients are sometimes deaf to the remonstrances of the architect, and in default of any permanent authority, the voice of interest can alone make itself heard. At the same time it must be stated that the legal difficulties and impediments to a scientific combination of main and house-drainage are so great, that a proprietor must have the wealth of Crœsus and the patience of Job, if he attempts to carry it out single-handed, although no practical difficulty exists.

Do you find the four-inch tubular drains keep themselves clean?—Whenever an opportunity for opening and examining them has occurred we have found them perfectly clean. Whenever a stoppage has taken place it has invariably arisen either from their not having a sufficient fall, or from the access to them not being sufficiently protected. In my own residence the whole drainage passes through a *three-inch* pipe, and I have hitherto experienced no inconvenience.

Do you find the junctions keep themselves clean?—Perfectly so. Of course I speak of those made with an easy curve; where they are at right

angles they frequently become obstructed; but under the Commission we never suffer them to be used. Mr. Cresy, jun.

You were instructed by the Commissioners to examine and classify the plans for the drainage of the metropolis, did any of them make back-drainage a main feature of their projects?—So far as I at present remember, none of them; some may have introduced the subject incidentally in their memorials, but had it constituted a main element in their plans, I should have retained a distinct recollection of it, having been anxious in examining them carefully to select any striking point as a *characteristic* of the individual scheme.

Did the competitors appear to deviate from the old practice of draining down the centres of the streets?—I think none of them; certainly the great mass of the plans was entirely upon the old system.

What, in your opinion, would in general be the additional expense to the tenants incurred thereby?—Of course I can only reply to this question in a general manner, but should say that I have known instances of various kinds in which the excess of expenditure would vary from 35 per cent. up to 250 per cent., or twice and a half as much.

Did the competitors require additional supplies of water?—The great bulk of them did.

Did any schemes imply a combined system of water supply and house-drainage?—Most of them appeared to consider the water supply as of equal importance with the drainage questions; but they did not go into any detail on the subject, contenting themselves generally with indicating the source of water supply, and the mechanical means for raising it.

Did these schemes appear to evince a knowledge of the effects of concentrated house-drainage in reducing the size of main lines and the superfluous dimensions of the present sewers?—So far as the *internal* evidence of the plans themselves goes, to which alone I am enabled to speak, I can safely say that they did *not*. Of course it is distinctly understood that I speak solely of the plans, and am not in any way pronouncing upon the information possessed by the authors on these points.

Did you find any extensive advance upon the system which has hitherto regulated the metropolitan drainage?—No. Of course the proposals of many were on a much larger *scale* than anything hitherto done, but I think I may safely say that no principle remarkable for its novelty in an engineering point of view is to be found among them. I do not mean that neither ingenuity nor merit is to be found there, but that no new *scientific* principle is advanced by them, nor any novel practical application of an existing principle; hence I cannot say that any advance upon existing systems has been made, or rather there being at present nothing deserving the name of a system, that a scientific basis for one has been created by the competition.

Were the competitors men of extensive practice?—Among so large a number many well-known names are to be found, but not those who are considered as our principal engineers, and the greater portion were, comparatively speaking, unknown to fame; there were some, indeed, who were not engineers at all.

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Mr. Edward Gotto examined.

1. Are you not assistant engineer to the Metropolitan Commissioners of Sewers?—I am surveyor to that Commission.

2. Before you entered into their service had you had much experience of house-drainage and tubular drainage?—I had, as town surveyor of Dover, in Kent.

3. Since you have been in the service of the Commission have you had further experience therein?—Yes, and have devoted a great deal of attention to it.

4. Have you also laid down drains at Dover, and seen much of other drains?—Yes, and, generally speaking, I have seen a great deal of tubular drainage in action.

5. Is your extent of observation of tubular house-drainage so wide that you think its success complete with regard to houses of different conditions?—My experience of the action of tubular pipe-drainage embraces a great variety of cases and circumstances, and I am satisfied as to its complete success when properly laid, with a constant supply of water, and of its superiority over brick drains.

6. Not only theoretically but practically?—Yes; that is to say, my observations have been quite sufficient to lead me to conclude that tubular house-drains, properly constructed, and with a sufficient domestic supply of water, will keep themselves clean. My opinion is, that the domestic supply of water need not for this purpose be increased beyond its present amount in ordinary cases, but this opinion presupposes that every house had a skilfully devised water-supply, efficiently connected under improved arrangements with the house-drains. A large proportion of the existing supply runs to waste, frequently causing dampness to the premises, without affording any benefit to the drains.

7. You have had occasion to prepare plans for blocks of houses at Goulston-street, Whitechapel; Church-lane and Carrier-street, St. Giles's; and Jennings-buildings, Kensington?—Yes, as surveyor to the Metropolitan Commissioners of Sewers.

8. What was the size of the block of houses you laid down at Goulston-street?—About 9 acres.

9. What size house-drains did you propose?—The private house-drains were proposed to be 4 inches in diameter, the houses being of the smaller class.

10. What is the smallest inclination you would allow in these pipes to keep themselves clean?—2 inches in 10 feet, or 1 in 60, and as much more as could be procured; but with an inclination of 1 in 60 they would keep themselves clear.

11. At that inclination what length of time would it take for a 4-inch pipe to discharge a day's supply of water; say 100 gallons?—If this quantity of water were already in a cistern of the ordinary elevation, and the 4-inch pipe communicating therewith, the water would be discharged in about two minutes after the pipes were full: the time the drain would take to fill, would of course be in proportion to its length, and the velocity of the water would depend also upon the pressure given by the elevation of the cistern. But under a system of constant supply, the water-pipes being always full and under pressure, the day's supply

would, if given all at one time, pass away as fast as it was so given, the rate of discharge then being according to the size of the supply-pipe. Mr. Gotto.

12. Supposing the surface-water to be discharged through the house-drains, at what rate would such a pipe discharge an hour of the heaviest rain-fall?—In about 5½ minutes if it were all let off at once, or about 10 times faster than the rain came down: 2 inches in depth of rain in one hour falling upon the garden, roof, and yard of a house and premises, 15 feet in the front and 60 feet deep, would require a drain to afford the necessary and immediate relief capable of carrying off 15 gallons per minute, whereas a 4-inch drain, with an inclination of 1 in 60, or 2 inches in 10 feet, would discharge 162 gallons per minute, if it were kept full.

13. Take the Goulston-street block of houses: what is the largest size of drain?—Twelve inches in diameter: there are 402 houses, but several outlets were proposed, so that about 50 houses would drain through a 12-inch pipe.

14. As a general proposition, if the house-drains kept themselves clear, the mains should likewise keep themselves clear?—Yes; there is this greater reason for that, because, as every house-drain adds its volume of water to the stream in the main channel, it imparts an additional velocity, and these concentrated currents produce a scouring power in due proportion. Stoppages in tubular drains are usually discovered between the main-drain and the house, and arise from inadequate and improperly applied water-supply and insecure inlets. The chief obstacle to be overcome in house-drains is not the conveying away the liquid refuse, that is, the water-supply after it has served its domestic purpose, for this could be effected through a discharge pipe but little larger than the supply pipes; the difficulty is so to secure the several inlets, namely, the water-closet, sink, yard, and area grating, as to prevent the passage of solid matter, such as is difficult of suspension and so of removal in water. In one instance, the pipes on being taken up were found filled with ashes; in another, which I examined, the stoppage was occasioned by the ends of two pipes being placed about 12 inches apart instead of joined, and the intervening space roughly filled up with bricks on edge.

15. If you take 1 in 60 for house-drains, what would you have for small branch-drains that come into the sewers?—That depends on a variety of circumstances, but, generally speaking, the inclination of the outlet or lower end of the main sewer-pipes in a well-arranged system of drainage should not be less than 1 in 240, and as much more as possible; but large sewers, which form main lines, may be as flat as 1 in 1000, or 4 or 5 feet in a mile.

16. Then with the concentrated flow a less inclination would suffice?—This is found practically the case. We see it every day. The addition of more water to the stream in a sewer exercises a far greater influence on the velocity than does increasing the inclination; for a circular sewer-pipe *full* at the head will discharge four times the quantity of water discharged by the same sewer-pipe *half-full* at the head in the same time; and this last quantity will be again four times greater than that discharged by the same sewer-pipe *quarter-full* at the head, but if the quantity of water be not so increased in the sewer, such a discharge, velocity, and scouring power as that described above, cannot be

Mr. Gotto. attained, even though the inclination be increased to any extent. Hence, where waters are gathered together in one channel, the inclination becomes of secondary importance within certain limits.

This law is fulfilled in the abstract in open streams and rivers; they are steep at their source, and, as along their course their tributaries pour in, the inclination is in proportion diminished as the waters reach the outlet.

The practical inferences to be drawn from these data are—

1st. That the addition of an equal quantity of water to a sewer will impart very great scouring and cleansing power.

2nd. That in secondary and main sewers and pipes, inclination is not of so much consequence as it is in house-drains, where it is more under control, the effect being produced in the former by the addition of the collateral streams.

3rdly. That the inclination of 4-inch house-drains should not be less than 1 in 60; that of main sewer-pipes not less than 1 in 240; and that of main lines may be 1 in 1000.

17. You carried all these house-drains from the back, did you not, where you could?—Yes; these plans were designed on that principle of drainage.

18. Do the smaller house-drains keep themselves clear, according to your experience, while the larger one would be choked?—They do: in very large house-drains, the water being spread over a large surface, and there being but little hydraulic depth, the water has but little power to remove obstacles; this is so in tubular drains, but obtains to a still greater extent in brick drains; the reverse is the case in contracted channels of a tubular form and uniform bore.

19. You are aware that in common drains there is a great deal of soakage, and a consequent loss of water?—In brick drains I have found the sewage matter act chemically upon the mortar joint, so as to produce rottenness, and the sewage soon penetrates through the bottom. One instance amongst many others occurred but recently, in which I had occasion to examine the drains of the St. Marylebone workhouse, where I found a well about 8 or 9 feet below an adjoining brick drain had been contaminated by its contents, and had been in consequence disused for some years.

20. Then there will be an economy in the actual discharge from a house in this way, and a concentration of force, if it be sufficient to keep not only the drains but the mains perfectly clear?—Yes. There will be required a less quantity of water to be supplied to a house to keep its drain clear, if that drain be small, than if it be large, and the force of the water will be more concentrated and calculated to bear upon any obstacle requiring to be removed, and by judicious arrangements these streams may be made to act upon the flow in the main channel so as to ensure their perfect and permanent self-action.

21. Then, in point of fact, according to your experience, if properly constructed, an additional supply beyond the present domestic supply of water will not be needed?—Not for keeping the drains clean; and, taking into consideration the quantity and nature of the matter to be removed from houses by means of drainage, I am confirmed in the opinion that the average quantity of water now found to be supplied to

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the ordinary class of houses is sufficient for that purpose, if judiciously applied. For it is estimated by Bousingault, and confirmed by Liebig, that each individual produces $\frac{1}{4}$ lb. of solid excrement and $1\frac{1}{4}$ lbs. of liquid excrement per day, making $1\frac{1}{2}$ lbs., or 150 lb. of semi-liquid refuse per 100 individuals from the water-closet. But there is other refuse resulting from culinary operations to be conveyed through the drains: the whole may be about 250 lbs. for 100 persons. Now 3 gallons or half a cubic foot of water will carry off 1 lb. of solid fæces through a 6-inch pipe with an inclination of 1 in 10, and 720 gallons per day would suffice to remove the domestic refuse from a building containing 100 persons, that is about 7 gallons for each person. It has been stated by water companies that each person on the average was supplied with 13 gallons per diem, but a number of cisterns gauged in St. Marylebone and Paddington showed only 3 gallons as having been so supplied. (*Vide* House of Lords Report, 1840, on Water Supply, questions 385, 394, 486.)

In my opinion, if 6 gallons of water, or 1 cubic foot, for each person per diem were supplied and advantageously passed through properly laid house-drains, with a sufficient inclination, of well-judged materials and size, it would suffice not only to keep the drains clean, but to carry off the sewage produced in the houses. It is not here intended to affirm what quantity of water is necessary for domestic use, but simply for the purposes of efficient drainage; but any additional quantity that might be deemed requisite for baths, wash-houses, &c., would be so much more benefit to the drains; and when it is remembered that a day's supply of water can be carried off by a 4-inch drain in two minutes after the pipe has become filled, as has been already shown, there will be no question as to the capability of a 4 or 6 inch house-drain to take off the additional quantity supposed above.

A prospective estimate of 25 gallons each person per diem was advanced in the First Sanitary Report, 1847, p. 53. But in my judgment not more than half that quantity would be used, for under the present intermittent supply the water passing through the house-drains varies from about 14 to 17 gallons per day per individual; and considering the enormous waste involved in that defective system, which would not be the case in a system of constant supply, it will be seen that these observations justify my opinion. An instance of the waste of water under the present system may be exemplified by an examination I have made of the flow of water through a pipe-sewer in Whitechapel. The water is on for about $1\frac{1}{2}$ hour each day. There are about 900 gallons delivered into the five water-butts that supply the six houses, draining through a 9-inch pipe-sewer. The water-butts hold together 210 gallons, and all the rest runs to waste; 540 gallons of this is found by gauging to pass away through the drain. In another instance which has come under my notice, in John-street, Edgware-road, six houses having water-closets and cisterns are supplied by the West Middlesex Water Company. The cisterns together contain, before the water is newly turned on, 696 gallons, and after the water is turned off and they are full, 1086 gallons; the quantity therefore used and passing through the sewer in the two days of interval is 396 gallons; but on the water-day 1188 gallons passed through, so that there was 396 gallons used and 1005 gallons wasted in two days. The average quantity of water actually used in thi

Mr. Gotto. place is about 5 gallons per day for each person. In Park-place, St. James's, the Grand Junction Water Company supply nine houses (one a large mansion) with water, and during the hour of supply there passes through the 12-inch sewer-pipe from these houses 4320 gallons, while the quantity actually used per day and passing through the sewer when the water is not laid on is 3660 gallons, the quantity wasted being about as much as that used. It will be perceived that economy is out of the question, and that unbounded extravagance and waste pervade the system.

22. In respect to back drainage, what is the average length of drain per house compared with front drainage?—About one-third.

23. In the Goulston-street block of houses, what was the average distance gained by back over front drainage per house, and upon the whole number of houses?—That block of houses is favourable to the back drainage, and the average gain per house by such an arrangement over the ordinary plan of laying the drain through each house into the main in the sewer-pipe in the street or place would be about 35 feet, and the approximate saving in length for the whole block would be about 14,000 feet.

24. In that instance did the back drainage enable you to gain a fall which you could not through the front?—In that instance the advantage in improved inclination would be in proportion to the length of drain saved by adopting the arrangement of back drainage. For instance, if the sewer-pipe were in the street 9 feet deep, the house-drain passing from the water-closet at the back through the building into the sewer, the length of the house-drain would be, say 45 feet, whereas, if the sewer-pipe passed along the back close to the water-closet and other inlets, the length of house-drain would be about 10 feet, according to the annexed plan, and therefore the advantage in the inclination is evident, and that advantage is acquired just in the part of the system where it is most required, namely, in the single drain, which has to do its own work unaided by the combined force of other streams. There are, however, other circumstances under which the foregoing reasoning would not apply, as in the main sewer in the front of a row of houses, previously receiving a large amount of drainage, which, being more than an equivalent for inclination, maintains a sufficient velocity with a less fall, passing the fronts of the houses at such a greater depth as would afford a better inclination by the longer drain through the house, than by the shorter drain discharging at the back into the sewer-pipe, which must rise more steeply on account of receiving less drainage, till at the upper end it might be but a few feet only below the surface. This will occur in a great many instances; and leads to the conclusion that no general rule can be laid down for back drainage that will dispense with the exercise of judgment and skill on the part of well-qualified officers.

25. How much quicker will the refuse be discharged by back drainage than by the front?—The removal of refuse from a house will be accelerated both by the shorter length of drain secured by back drainage and the improved inclination attained thereby. It would be carried from the house about four times faster than if it has to pass through the house into the sewer-pipe in front.

26. Suppose you got an outfall for this block of houses, and the table

to drain to was equal; what would be the difference in point of time with front and back drainage?—The extra length of drains required if they were to pass through the houses I estimate at about 14,000 feet; and a day's supply of water for 402 houses, at 100 gallons each, would be 6700 cubic feet. This quantity would be discharged through 4-inch pipes, laid at an average inclination of 1 in 40, and half-full at the head, in about 36 hours; but it is to be observed, that this total length is made up of the several distinct lengths from each house, through all which the sewage would be passing at the same time, and therefore the difference in point of time can only strictly be said to be that required for the passage of the sewage from one house through its extra length of house-drain. Mr. Gotto.

27 and 29. Will you compare the frictional surface of back tubular drainage, not only with front tubular drainage but with front drainage on the old plan by brick drains and brick sewers?—To calculate the frictional surface of the three descriptions of drainage set forth in this question, and give the four comparisons required, would involve laying out the several systems, and occupy myself and assistants many days. I therefore confine the answer to a single house, of which there are 402.

Assuming the average proportion of length as in former questions in reference to this block, namely, as 10 feet is to 45 feet, the comparative frictional surface will be as follows:—

Back drainage, 4-inch pipes . .	126	superficial feet.
Front drainage, 4-inch pipes . .	545	,,
Ditto, 9-inch brick drains . .	1272	,,

28. To produce the same effect, supposing you have the minimum supply of water for back drainage, what is the additional supply of water required to overcome the additional amount of friction by front drainage?—Confining the question to the house-drains, no additional quantity of water would in such a case as that assumed in the foregoing questions be required to produce the same effect in front drainage as is produced in back drainage.

The question requires much consideration, and the result would vary materially in every different case. Assuming all other points of comparison to be similar, if the inclination be such as is required for house-drains, or 1 in 60, this inclination, together with the minimum supply of water, would generate an accelerating force by which the sectional area of the water would be decreased through the whole length of the pipe in proportion to the increased velocity; therefore the moving power in the lower end of the pipe will be made up by such increased velocity to the momentum which obtains at the upper end of the pipe, by the increased sectional area of the water, so maintaining nearly an uniform motive power throughout the 45 feet of pipe required for front drainage as it would through the 10 feet of pipe here supposed as the length required for back drainage: the accelerating force overcoming the additional amount of friction.

29. [See No. 27.]

30. What would be the total area or evaporating surface of filth in this block of houses, if, in addition to cesspools, there were drains from all the houses on the old plan of brick drainage?—The same reasons oblige me to confine this answer within the limits of the preceding; and

Mr. Gotto. supposing the whole length of all the pipes to be half-full, or giving the maximum, the result will be thus:—

Cesspool (say 3 ft. × 3 ft.) . . .	9	feet superficial.
Drain, 9-inch diameter	34	,,
	43	,,

31. What is the additional quantity of water you estimate would be required for the Goulston-street block of houses, to keep the house-drains clear and the sewers clear, if they were drained on the old plan? Or what would be the gain in water in this block of houses by increasing the speed as well as lessening the friction?—I feel that the experiments and observations hitherto made on the quantity of water required to move bodies in brick drains are not sufficient to justify my giving a very explicit answer to this question; but, comparing the 4-inch pipe-drains of a house laid at 1 in 60, and 10 feet long, with a 9-inch brick drain at an inclination of 1 in 40 and 45 feet long, as far as present experience justifies the comparison, I am of opinion it would require three times the quantity of water to produce the desired effect in the 9-inch brick drains.

32. What do you estimate the expense per house of tubular front drainage and back drainage?—Referring again to the plan of a house in New Castle-street, Whitechapel, the estimate for *back* drainage (not including the cost of water-supply) would be as follows, if the pipes were made and the work were done by contract under the Commissioners of Sewers:—

Water-closet Apparatus and Drain.

	£.	s.	d.	£.	s.	d.
Emptying and filling up the cesspool .	0	12	0			
Digging, filling in, &c., for 8-feet pipe-drain, at 4*d*.	0	2	8			
Making good to walls and floor of water-closet over drain, at 3*d*. .	0	2	0			
8 feet run of 4-inch pipe, at 3*d*. . .	0	2	0			
Laying ditto, at 2*d*.	0	1	4			
Extra for junction	0	0	4			
Fixing ditto	0	0	2			
Water-closet apparatus complete, with stool-cock	0	10	0			
Fixing ditto	0	2	0			
10 per cent. for contingencies . .	0	3	6			
				1	16	0

Yard Sink and Drain.

	£.	s.	d.
Digging and filling-in for 6 feet run of 4-inch pipe, at 4*d*. . . .	0	2	0
Making good yard surface, 6 feet, at 3*d*.	0	1	6
6 feet run of 4-inch pipe, at 3*d*. .	0	1	6
Carried forward . .	0	5	0

	£.	s.	d.	£.	s.	d.
Brought forward . .	0	5	0	1	16	0
Laying ditto, at 2*d*.	0	1	0			
Extra on junction	0	0	4			
Fixing ditto	0	0	2			
Double trap, with sink . . .	0	3	0			
Fixing ditto	0	0	8			
10 per cent. for contingencies . .	0	1	0			
				0	11	2

Kitchen Sink and Drain.

	£.	s.	d.	£.	s.	d.
Stoneware kitchen sink . . .	0	4	0			
Fixing ditto and making good . .	0	1	6			
9 feet of 2-inch drain-pipe, at 2½*d*. .	0	1	10½			
Laying ditto, at 2*d*.	0	1	6			
Digging for ditto, at 4*d*. . . .	0	3	0			
Making good paving, &c., at 3*d*. .	0	2	3			
10 per cent. for contingencies . .	0	1	6			
				0	15	7½
Cost of *back* draining one house, including water-closet, and kitchen and yard sinks				£3	2	9½

Estimate for the *front* tubular drainage of the same house in this block, exclusive of cost of water-supply apparatus, if the pipes were made and the work were done by contract under the Commissioners of Sewers :—

	£.	s.	d.	£.	s.	d.
Emptying and filling up cesspool .	0	12	0			
Digging and filling in to 45 feet of 4-inch pipe, at 4*d*. . . .	0	15	0			
Making good to walls and floor of water-closet and room of the house, 30 feet, at 3*d*.	0	7	8			
45 feet of 4-inch pipe, at 3*d*. . .	0	11	3			
Laying ditto, at 2*d*.	0	7	8			
Extra for junction	0	0	4			
Fixing ditto	0	0	2			
Water-closet apparatus, with stool cock	0	10	0			
Fixing water-closet	0	2	0			
Relaying 15 yards of carriage-way, paving, &c., at 1*s*. 6*d*. . . .	1	2	6			
10 per cent. for contingencies . .	0	5	0			
				4	13	7
Digging and filling for 8 feet of 4-inch pipe, at 4*d*.	0	2	8			
Making good yard surface, &c., 8 feet, at 3*d*.	0	2	0			
Carried forward . .	0	4	8			

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	£.	s.	d.	£.	s.	d.
Brought forward .	0	4	8	4	13	7
8 feet 4-inch pipe, at 3*d*. . . .	0	2	0			
Laying ditto, at 2*d*.	0	1	4			
Extra on junction	0	0	4			
Fixing ditto	0	0	2			
Double trap, with sink . . .	0	3	0			
Fixing ditto	0	0	8			
10 per cent. for contingencies . .	0	1	3			
				0	13	5
Kitchen sink and drain, as in the last estimate				0	15	7½
Cost of *front* draining one house, including water-closet and kitchen and yard sinks				£6	2	7½

These estimates are only for the works of private improvement, and do not include the cost of the main sewer-pipe in either case: with this addition the total estimates would be as under:—

Back Tubular Drainage.	£.	s.	d.	Front Tubular Drainage.	£.	s.	d.
14 ft. 6 in. for 6-inch pipe-sewer, and making good to yard surface at 2*s*. . . .	1	9	0	14 ft. 6 in. frontage for 6-inch pipe-sewer, and making good carriage-way paving at 2*s*. 10*d*. . . .	2	1	1
Private house drainage (see foregoing estimate) . . .	3	2	9½	Private house drainage (see foregoing estimate) . . .	6	2	1½
Total	4	11	9½		8	3	2½

33. What is the additional expense of front drainage where it is requisite to cut through flooring, &c.?—The extra cost involved by front drainage of cutting through the floor, and making good the same and the carriage-way in the front of the house, upon which these estimates are founded, would be 1*l*. 8*s*. 2*d*.

34. What is the expense per house and district upon the old system, with brick drainage running through to the front of the house, with brick sewers in the streets, &c.?—The expense for the drainage of one house, with cesspool and brick drains into the sewers, I estimate thus—

	£.	s.	d.
Digging, filling, &c., for 50 feet of 9-inch drain from sewer to cesspool, and sink in yard, at 7*d*. per foot	1	9	2
Making good floors and walls through houses, 35 feet, at 4*d*.	0	11	8
Making good carriageway-paving, 15 yards, at 1*s*. 9*d*.	1	6	3
Carried forward	3	7	1

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	£.	s.	d.
Brought forward	3	7	1
Digging and carting 3 cubic yards of earth from cesspool, at 3*s*.	0	9	0
50 feet run 9-inch barrel-drain, at 1*s*. 4*d*. . .	3	6	8
25 feet superficial reduced brickwork for cesspool, at 10*l*. 4*s*. per rod	0	18	9
Riser and seat to privy	0	6	5
Brick trap in yard	0	12	6
Yorkshire stone sink in kitchen, with bell-trap and pipe into drain	1	12	0
10 per cent. for contingencies	1	1	6
Cost of drainage of one house under the old plan, exclusive of main sewers	11	13	11

This estimate does not include the expense of main brick sewers, such as would formerly have been constructed, the whole expense for which, in the block of houses of 9 acres, alluded to before, would be 3755*l*., or 7*l*. 8*s*. 6*d*. per house for the use of the main sewer alone. The total cost would be—

	£	s.	d.
House-drainage	11	16	11
Main sewers	7	8	6
	£19	5	5

35. What is the gain in the water-power, and what is the gain in the expense of drainage?—There would be a saving of about 38,400 gallons of water per day on 400 houses, and a gain on the expense of drainage of about 5680*l*. As to the water-supply, as I have already stated, 6 gallons for each person per diem would be sufficient for keeping skilfully-constructed house-drains clear; and supposing eight persons to each house, the average in this block would require 48 gallons per house; while it is my opinion 150 gallons would be required to keep drains of such a house clear if constructed of brick according to the Metropolitan Buildings Act, and as is the case for the most part throughout the metropolis where any house-drainage exists—the tubular pipe-drainage substituted within the last few years being the exception to that which generally prevails. The detail-estimates sufficiently explain and justify the gain in the cost given above of back-drainage over the old plan of brick drains and sewers. Indeed it has been found to be altogether impossible to drain the lower description of houses in the metropolis upon the old plan, on account of the enormous expense; and this is the reason that all the poorest localities, where drainage appliances are most required to remove the rapidly-accumulating filth resulting from the overcrowded state of the dwellings, are entirely destitute of such important requisites of health and comfort. The same reason may in a great measure be assigned for the prominence such places hold in the Registrar-General's repeated reports of deaths, and why they are so conspicuous in times of cholera.

Mr. Gotto. 36. In this Goulston-street plan you not only contemplated the removal of all cesspools, but also the substitution of water-closet apparatus?—Yes. The sanitary improvement of that place, as well as of others upon which I have reported from time to time, embraced the substitution of a water-closet apparatus for the cesspool.

37. Have you any idea of the additional quantity of water the water-closet apparatus would require for this block of houses?—The water now running to waste under the present imperfect supplying apparatus would more than suffice for the use of the water-closets. In the instance before given three-fourths of the water run to waste during the time of supply.

38. What is the average consumption per house where supplied from butts, the supply being on alternate days?—The average quantity of water actually consumed per house is about 57 gallons in the lower neighbourhoods, such as Whitechapel, and where each house contains 10 persons on an average. This is ascertained by selecting a number of houses where the water-butts are emptied before the next supply fills them. But the houses in such places have not all cisterns; most of the inhabitants procure their water from the stand-pipe in stone jars, many others have pails and kettles, but few have cisterns or water-butts.

39. Did you find that the butts were not emptied on the second day?—103 water-butts and cisterns out of 141 which have been examined in this place were not emptied before the next supply came in.

40. Did you find the foundation of the houses very damp there?—The lower floors of the houses thus imperfectly supplied with water, and having no drainage, are very damp, especially where stand-pipes are used to deliver the water. In some places the yards are completely flooded in consequence. And this dampness, besides aiding in the production of sickness, hastens the decay of house property, and is thus the cause of much permanent damage.

41. Do you think that the damp was greater than could be accounted for by the mere rainfall?—There can be no doubt of it; the overflow from water-butts often passes into the cesspools, where there are any, and penetrates to the house foundation: it is periodical, certain, in large quantities, and always in one place, and hence is sure to accomplish the work of destruction, though perhaps for a time unnoticed. For this reason the subjects of water supply and drainage are inseparably connected: water should only be very cautiously administered where no drainage exists; and where houses are supplied with water there should be drains to carry it away, and both should be under one superintending jurisdiction.

42. Where the houses were drained could you find an average discharge of water?—I have had several opportunities of making such observations. In a case before alluded to at Goulston-street, 6 houses, standing on an area of 223 square yards, are supplied with 900 gallons of water by the New River Company daily, for about 1½ hour, into 5 water-butts, containing each 7 cubic feet, or together 210 gallons. The average discharge here through the 9-inch stoneware drain, during the time the water is being delivered, is 330 gallons per hour, or 495 gallons during the time of supply, and about 6 gallons per hour during the remainder of the day. This was only the ordinary flow from the houses, and in fine weather.

Observation No. 2.—About 380 houses, draining into a 12-inch pipe laid along the towing-path of the Regent's Canal, near the Caledonian-road :— Mr. Gotto.

Date.	Total Discharge in 24 hours.	Discharge per House in 24 hours.	Greatest Flow per hour.	Least Flow per hour.
	Gallons.	Gallons.	Gallons.	Gallons.
1850. Thursday, January 10, not a water-day . .	18,927	50	4200 (From 1 to 2 P. M.)	252 (From 6 to 7 A. M.)
Friday, January 11, water-day . . .	26,412	85	12,600 (From 10 to 11 A. M.)	252 (From 6 to 7 A. M.)
Saturday, January 12, water-day . . .	39,669	104	12,600 (From 7 to 8 A. M. from 3 to 4 P. M.)	186 (From 6 to 7 A. M.)
Monday, January 14, not a water-day . .	14,169	40	3150 (From 9 to 10 A.M.)	140 (From 6 to 7 A. M.)

The greatest depth of water in the 12-inch pipe during these experiments was 3 inches, but little more than one-third of its sectional area.

43. As a general rule, may it be said that nothing is sent down the soil-pans that the water will not carry away, and that the more the junctions are the greater will be the rapidity of the discharge ?—I have found in my experience of tubular house-drainage that what usually passes down the water-closet will be conveyed away if there be an adequate supply of water. When stoppages are discovered in house-drains having a sufficient supply, they are generally found to arise from the improper construction of the drain, irregularity of the inclination, imperfect joints, &c., although the matter accumulated is very frequently hair and grease, which would have, however, readily passed away, had the obstructions not been left in the drain itself at its construction ; this appears from the upper and perfect part of the drains being quite free from any appearance of such matter, and the point of stoppage being at the imperfect part. If junctions be properly moulded and skilfully laid in, the contributions of water they discharge will accelerate the velocity of the united current in the main sewer-pipe, and therefore all the branches from the various parts of the house should be short, and united to the principal house-drain as soon as possible. But if they are laid in at right angles, each junction tends rather to impede the velocity by discharging its stream across the direction of the current in the house-drain. The same principle, of course, obtains with regard to main sewer-pipes and brick sewers.

44. What would be the additional expense for cisternage, for Goulston-street block of houses, to give the locality a constant supply? —The expense of constructing a water-tank at a sufficient elevation, and of a capacity to contain two days' supply of water for this block of houses, would be about 160*l.* The water would be supplied by the New River Company, and the mains always full and charged. Several years would elapse before any great and extensive works of improved water-supply could be completed ; and the plan here suggested and detailed in my Report upon Church-lane, St. Giles's, of dealing with blocks of houses in the poorest neighbourhoods, and pro-

Mr. Gotto. viding them with small systems of constant water-supply connected with efficient drainage, cannot fail of affording the desired relief in the mean time, and that with a considerable saving over the present intermittent and wasteful practice. Moreover, the mains and domestic distributing pipes and apparatus would be adapted to and ready for the general improvements contemplated whenever they should be carried out; and if this plan were adopted in such places, immediate relief might be afforded where it is most required, and those very extensive works of distribution would be in progress, which would otherwise occupy many years, if their commencement be delayed till the source of metropolitan water-supply be decided.

45. What would be the rate of additional expense of construction at other places to make the present intermittent supply of water a constant supply?—In Church-lane and Carrier-street, St. Giles's, there are 110 houses. I have prepared plans and estimates to supply these houses with water in the manner before described. The water-tank and mains of fire-clay would cost 262*l.* 10*s.*, or 2*l.* 7*s.* 7*d.* per house, that is, provided the water-mains were laid in the same trenches and at the same time as the main sewer-pipes, for the digging and reinstatement of the paving, which form the largest items in the expense, would be thus in a great measure saved. The expense per house for the service-pipe to the ground-floor, stop-cock, stool-cocks, and tap to the sink, would be about 16*s.* 6*d.*; this, with the cost as above of general works, would be 3*l.* 4*s.* 1*d.*

46. State what is the average size and cost of pipes?—The water-mains of fire-clay would be required about 3 inches in diameter (at 3*d.* per foot) for such a block of houses and Goulston-street, and the house-service 1 inch in diameter, at a cost of 1½*d.* per foot. These prices are given, assuming that the manufacture of pipes for this purpose would be carried on upon a principle of economy commensurative with the contemplated demand.

47. Will you state the extra supply of water which might be consumed by a proper system of surface-cleansing by jet?—This will depend upon the pressure under which the water is delivered and the frequency of plugs, but it appears, from experiments, that the average quantity of water required for street cleansing after this manner would be about 1 gallon for every superficial yard of paving each time.

48. What is the expense of that mode of cleansing, compared with that of scavenging?—It is estimated that 100 yards of paving can be cleansed by the hose and jet for 2¼*d.* each time; and if this be done every day, it would amount to 14*d.* per 100 yards per week. It should be observed that the plan of washing the mud from the streets into the sewers involves the expense of removing it from them; for it is found that the heavy matter from the carriage-ways is the most difficult of removal from the sewers, concreting on the bottom, and frequently requiring to be brought to the surface by hand labour. Beyond this item in the total expense, for which no accurate estimate can be made, there is another in sweeping and scraping solid matter, which cannot be removed effectually from the surface by the use of water only. It is found also that constant sweeping, by hand-labour or machine, during the day, is the best means of preventing the accumulation of mud in streets. This process also, to a very great extent, supersedes the

necessity and expense of watering the streets, on account of all dirt being removed as soon as it is created, and before it can become dust. Where there is a constant and rapid accumulation of filth, there should be as constant a means of removal, and this cannot be the case with the hose and jet. It is a matter of daily experience that sweeping will cost per 100 yards per week— Mr. Gotto.

Labour	$5\frac{1}{2}d.$
Brooms, &c., and superintendence, about . .	1
	$6\frac{1}{2}d$
To this must be added the cost of watering when it is required . . . . . . The charge is about $2d.$ per yard for the season of about half the year.	$7\frac{3}{4}$
Total cost per 100 yards per week for sweeping and watering	$14\frac{1}{4}d.$

There is no item in this estimate for cartage, since the value of the manure is found to be equivalent to it.

49. Have you, in the course of your experience, found that, as a general rule, there is any substantial difficulty in the way of back-drainage?—I have not hitherto found any insurmountable mechanical difficulties in the way of constructing back-drainage. On the other hand it will be seen, by what has been already advanced, that generally speaking it possesses in practice many advantages over any other description of house-drainage. *First*, in point of economy, being on the average about *half* the cost of tubular drainage passing through each house to the sewer in front, thus bringing this important sanitary improvement within the reach of owners of the lowest description of house property. *Secondly*, it is more efficient; carrying off the refuse and filth from the houses much faster than by front-drainage, on account of the shorter length of drain required, while, for the same reason, there would be less chance of stoppages taking place, and less cost of repairs. It is found in practice desirable on this account to make house-drains as short as possible. *Thirdly*, it is more convenient, there being no necessity to disturb the floors and foundations of houses, either for the first construction or during repairs. But while there are frequent applications for back-drainage in preference to other more expensive plans made by owners of house property appreciating the advantages before enumerated, there are also many who delay the improvement of their property rather than execute the work upon such a principle. The difficulties to be encountered and provided against, in adopting this arrangement as a general principle, require serious consideration. *First*, as to one person's right of draining through his neighbour's house; *secondly*, as to individual liability to cleanse and repair drains laid under such circumstances. It is found that in this way considerable annoyance, trouble, and expense often fall upon a person, the drain of whose house is stopped in consequence of the carelessness (sometimes wilful) of his neighbours in sending down the drain matter it was never intended to convey. *Thirdly*, some inconvenience may be anticipated in apportioning the expense of construction of the main sewer-pipes in back-drainage, for, the size of the pipe at the back of the house at the lower end may be 15 inches, and gradually decreasing in size till

Mr. Gotto. it may be 6 inches at the back of houses at the upper end. Thus, while more expense will be incurred on the premises of the one than the other, yet the benefit would in either case be equal. These objections to the system may, however, be obviated by efficient arrangements under the authority of the Act of Parliament carried out by a properly organized staff of inspectors of house-drainage, to ensure and preserve its proper action.

50. Would not one and the same person suffice for keeping soil-pans in order, for the removal of dust, and for other work of a like description for keeping all clean?—Yes; and under well-devised arrangements the same inspectors might at the same time attend to the delivery of the water-supply, especially as under an improved constant water-supply the establishment of turncocks would be dispensed with, or their labour in a great measure lightened.

51. So far from an indisposition to having this cleansing carried on, is it not the fact that people themselves are willing to pay for it?—I have found it so, among the lower classes especially. It is stated in a Report presented by myself to the Commissioners of Sewers—"that in some parts of Whitechapel there are occupants of 60 rooms using three water-closets, and a poor women had undertaken to keep them clean for 1*d.* per week per room, producing 5*s.* per week; and it is stated to have been cheerfully and punctually paid. There were offers made at the time by tenants of rooms in Church-lane to pay the same weekly sum per room to keep a common privy cleansed. On this part of the property, consisting of 10 houses, this arrangement is adopted. A man is employed to cleanse the yards, privies, &c., and receives 1*s.* per day and his lodging." This plan is adopted in many other of the lower neighbourhoods of London, and, if matured, might be made far more easy and economical.

52. Would it not naturally fall, in the division of labour, to men in the position of turncocks also to be occupied in cleansing by the use of the jet, and keeping the taps, and other such portions of the distributary water apparatus, in order?—It would; and if the drainage, water-supply, paving, and building works, were placed under one jurisdiction, separate districts might be assigned to separate officers in respect of all these particulars.

53. Did you not contemplate and propose, in a Report, that this apparatus should be put down and kept in order by a contract for some years?—Yes, for five years.

54. What is the total cost per house per week that you estimate all this might be done, in a state of things in which there would be no accumulations, and in which water would simply be required to remove all out of sight?—All the cleansing works of paved yards, and attention to stoppages in drains, taps of water-supply, &c., would cost about one penny per house per week. I estimate that one person would attend to about 400 houses.

55. According to the ordinary rate of flow, what is the greatest length of time that any decomposing refuse could be removed from such a block of houses as the Goulston-street block?—About eight minutes, the greatest length of sewer-pipe being 860 feet.

56. At what rate would that flow have been in the main sewer?—The average rate of flow in the sewer would be about 24 inches in a

second; but this would vary at almost every part of the day in proportion to the quantity of water used. Mr. Gotto.

57. What length of time would the refuse remain in the drain of the kind of houses you have been speaking of?—But a very few seconds, the length of the drains under this plan being very short.

58. What would have been the expense of the earth-work in laying down this drainage, as calculated in your estimate?—

713 cubic yards digging	£62	7	9
458 cubic yards digging	40	2	1
2294 cubic yards digging	200	15	4
Total cost of digging for the main-sewer pipes	£303	5	2

59. What was the proportion of that expense to the whole?—Just half the cost of the whole work.

60. Supposing you had to lay down the water-supply apparatus separately from drainage and with distinct earth-work, what would be the additional expense?—For only the water-mains, about 210*l*.

61. If one man were on the spot to take care of the drains and sewerage, would it not be desirable to intrust to him the supervision over the water-apparatus?—Yes, very desirable: indeed, these two works, being inseparably connected with each other, ought to be under one control and management.

62. Would he not be the man to apply to immediately to procure speedy relief on occasions of fire breaking out in the neighbourhood?—He would; and being intimately acquainted with the water-apparatus, and having under his control the keys and plugs, much of the delay and confusion now universally experienced on such occasions would be obviated, while property and life would be in greater security.

63. Would not this plan tend to a reduction of fire risk upon this block of houses; and, if so, to what extent?—It is difficult to say to what extent, owing to the difference existing among the fire-offices in the manner of fixing the class of the risk: some offices would not take such property as this at all, but I am of opinion that the risk would be considered as reduced one-half by the adoption of such contemplated facilities for extinguishing fire.

64. Supposing the case of new buildings being contemplated, would it not be a desirable regulation that the surveyor or officer of the Sewers Commission, who would have to see to the putting down of the drains, should also see to the regulations as to party-walls being completely and effectively complied with?—Certainly; and very great inconvenience is now felt in consequence of these works being under different superintendence; the same person might do both with very little additional labour, trouble, and expense; and such an arrangement would materially facilitate the exercise of that control which ought to be had over the construction of drainage and water-supply works. It frequently happens that improperly constructed drains are surreptitiously introduced into the sewers from newly built houses, the existence of which the surveyor of sewers is ignorant of.

65. In laying down the distributory water apparatus at the backs of houses, would it not often avoid crossing areas, and thereby avoid exposing the pipes to frost?—It would diminish that inconvenience

Mr. Gotto. very much, since none of the pipes outside the house need be exposed: by this arrangement the water-apparatus would be shortened as well as the house-drainage, and it would be desirable to lay them down together and in the same trenches.

66. What extent of area do you think one man could keep in good cleansing order?—About 10 acres, if he had to keep the courts and alleys clean, as well as attend to the drainage and water-supply.

67. How much is the existing charge for such an amount of work?—About 200*l.* per annum for emptying the cesspools, without taking into account the expense of surface-cleansing and removal of solid refuse, for calculating the cost of which there is no data.

68. In respect to the amount of supplies in cisterns in this block of houses, did you notice circumstances to show the effect of exposure of water therein?—In many cases there was a very large deposit in the bottom of the cisterns, partly owing to the soot and dust, and partly arising from the foulness of the water supplied: the uncovered cisterns have uniformly more filth accumulated in the bottom than those which are covered, and are cleansed more often, in some cases once a fortnight, and even once a week: the water in these butts and cisterns is often frozen in the winter, and in the hot summer weather is deprived of its coolness, and, being stagnant, putrifies: from the information of the residents in this locality it is said to smell offensively in the summer.

69. In respect to the water distribution, will not this laying on of water, on a system of constant supply as contemplated, have the advantage of occasioning not only less exposure, but greater uniformity of temperature?—There need be no exposure in a properly laid constant supply of water, for the receptacles would be done away with; and by laying in the service-pipes at the backs of houses, as is here contemplated, the pipes would not as now pass along the area-wall above ground: it is most frequently in this part that the water freezes and the pipes burst at the ensuing thaw. For the same reason there would be an uniformity of temperature in the water, which could not be obtained by the present system.

70. Give the total expense of the apparatus for the distribution of water, distinguishing the expense of service-pipes per house, of the waste or return pipes from each house not properly called drains, and the expense of what would be called branch-mains?—Under a constant-supply system no waste-pipes would be required, and the digging and paving would be saved by using the same trench as the drain.

Estimate for water-supply apparatus to the house, shown on plan under the constant system.

15 feet of stoneware service-pipe, and laying, at 6*d.*	£0	7	6			
Stop-cock and fixing at the main	0	3	6			
Stool-cock and fixing to water-closet	0	2	6			
Joint at the water-main	0	0	4			
				0	13	10
For the branch-main, 15 feet of 3 in. stoneware main, and laying, at 8*d.*				0	10	0
				£1	3	10

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71. State also the expense of each water-closet apparatus laid down complete?—

The water-closet apparatus laid down complete would be	£0 12 0
Emptying and filling up the cesspool, about . . .	0 12 0
	£1 4 0

72. Also the expense of soil-pans supplied from waste-pipes?—The expense of soil-pans is 7*s*. 6*d*. each.

73. Also the expense of building common necessaries where a new one is necessary?—A public water-closet, constructed of hollow brick, similar to the accompanying plan, would cost about 10*l*.

74. Were you not directed by the Works Committee to examine and analyse the cost of production of drain-pipes and water-pipes; will you put in a table of the comparative expense of the present price of such materials, and the prices at which you reported they might be contracted for: include also in the table the present price of manufacture of stoneware pipes of the first quality, and the prices at which earthenware pipes might be manufactured, according to your report, of such quality as would serve for a water distribution?—I received instructions from the late Commissioners to make some investigations as to the cost and manufacture of earthenware pipes. With this view arrangements were made for moulding and burning some pipes in the improved kilns of the Ainslie Tile Company. The result of these experiments is contained in the following table, showing the quantity of material, and the cost of each part of the production. The total shows what may be called the neat prime cost of the goods at the kiln: a large percentage should of course be added for profit, carriage, &c. &c.

Cost at which tubular drain-pipes were manufactured in these experiments.

Size of Pipes, inches in diameter.	Materials.		Cost of Materials, Labour, and Burning, per 1000 Feet.					
	Clay.	Coals, 1 cwt. to a Ton of Clay.	Cost of Clay, say at 7s. per Ton, including Royalty, Digging, &c.	Labour in Pugging, &c., at 2s. per Ton.	Labour in Moulding, carrying to Drying Shed, and Attendance during Drying.	Cost of Coals, at 20s. per Ton.	Extra for Management, Kiln-rent, Waste, Labour, Packing, and Drawing the Kiln.	Total Prime Cost per 1000 Feet in the Field.
	Ton. cwt. lbs.	Cwt.	£. s. d.	s. d.	£. s. d.	s. d.	£. s. d.	£. s. d.
5	4 0 20	4	1 8 0	8 0	1 0 0	4 0	1 10 0	4 10 0
6	5 15 0	$5\frac{3}{4}$	2 3 0	11 6	1 8 9	5 9	2 3 1	6 9 4
$7\frac{1}{2}$	6 16 70	$6\frac{3}{4}$	2 9 9	13 7	1 14 2	6 9	2 12 0	7 16 1
$8\frac{1}{2}$	8 18 50	9	3 2 5	17 10	2 4 8	9 0	3 7 0	10 0 11

Each process of the manufacture is capable of very considerable improvement in respect of expense, time, and quality; but to bring this manufacture to maturity would require larger pecuniary resources and undivided attention. It will, however, be seen, by the following table, that, with the present incomplete and imperfect appliances, a very large

Mr. Gotto. reduction may be anticipated in the cost of these descriptions of goods, a result of the very highest importance, contemplating the immediate and large demand for sanitary purposes.

Table contrasting the prices of tubular drain-pipes.

Fifty per cent. is here added to the prices in the foregoing table, for profit, carriage, &c. &c.

Size of pipes, inches in diameter.	Lengths.	Red earthenware pipes if made by contract.			Red earthenware pipes at the present sale prices.			Stoneware glazed at the present sale prices.			Average Gain: On red earthenware pipes if made by contract over the present prices.			Average Gain: On red earthenware pipes if made by contract over glazed stoneware pipes.		
		£.	s.	d.	£.	s.	d.	£.	s.	d.	£.	s.	d.	£.	s.	d.
5	Per foot	0	0	1½	0	0	5	0	0	6	0	0	3½	0	0	4½
	Per 1000 feet	6	15	0	20	16	8	25	0	0	14	1	8	18	5	0
	Per mile	35	12	9	110	0	0	132	0	0	74	7	3	96	7	3
6	Per foot	0	0	2¼	0	0	6	0	0	7	0	0	3¾	0	0	4¾
	Per 1000 feet	9	14	0	25	0	0	29	3	4	15	6	0	19	9	4
	Per mile	51	4	4	132	0	0	154	0	0	80	15	8	102	15	8
9	Per foot	0	0	3¾	0	0	9	0	1	0	0	0	5¼	0	0	8¼
	Per 1000 feet	15	1	6	37	10	0	50	0	0	22	8	6	34	18	6
	Per mile	79	11	10	198	0	0	264	0	0	118	8	2	184	8	2

These experiments were carried on under many disadvantages and hindrances, calculated to increase most materially the ultimate cost of the production; and, from my experience, I am of opinion, that for the expenses exhibited in the table, and under more favourable circumstances, such as would obtain in a large and convenient establishment, pipes could be produced from common clay of sufficient strength for water distribution. One of the most important advances towards this state of perfection is that of submitting the pipe, when half dry, to an extreme pressure between two polished iron surfaces, whereby a density of substance and truth of form is attained, which imparts a superiority over the best description of glazed stoneware yet produced. A machine for effecting this purpose has been constructed and patented by Messrs. Burton and Sons, engineers, Blackfriars.

75. Allowing fifty per cent. on your estimated prime cost of production by the present improved methods, what would the production of such pipes at such prices reduce your estimate for the water-supply of the block for the supply of which you were called on to estimate and report on ?—About one-half.

76. What would be the total price, in each case, per house, of the reduced estimate for pipes, assuming that a constant supply of water would be provided, and cisterns be thus rendered unnecessary ?—

Estimate for laying on water to one house under the present intermittent system.

	£	s.	d.
24 feet super slate cistern, and fixing	£1	16	0
45 feet supply-pipe	2	5	0
8 feet service-pipe	0	6	8
10 feet waste-pipe	0	10	0
	£4	17	8

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Estimate for laying on water to one house under the contemplated constant system of supply.

See page 11 . . . . £0 13 10

77. What was your estimate of the expense of constructing gully-shoots on the improved construction, compared with the expense of former construction in Westminster and the City?—The price of gully-shoots was—

	£.	s.	d.
As constructed in the City	12	16	10
As constructed in Westminster district, in 1839....	7	17	6
Ditto ditto ditto in 1845....	4	4	11
Ditto at present of 9-inch stoneware pipes	3	17	0½
Ditto at present of 6-inch stoneware pipes	3	5	4
As they may be constructed of red earthenware pipe by contract under the Commissioners	1	10	3

78. In carrying out the improved drainage-works and waterworks, brickwork would, of course, be needed for man-holes, for the formation and arching over of culverts, &c.?—Brickwork will always be required in drainage, for the more important lines of sewers, and other works.

79. Your investigations as to the cost of producing drain-pipes will, of course, be applicable to the production of hollow bricks?—Under the direction of the late Commissioners I had some hollow bricks burnt at the time of making experiments on pipes.

80. Did you examine and analyse the prime cost of the production of hollow bricks?—I did, and the following table shows the neat prime cost at which hollow bricks could be made by contract under the Commissioners by the use of improved machinery and kiln:—

Prices at which Hollow Bricks could be made under the Commissioners, by the use of Improved Machinery and Kiln.

Size.	Quantity of Material used per 1000 feet.		Cost of Materials, Labour, and Burning, per thousand feet.						
	Clay.	Coals at 1 cwt. per ton.	Cost of clay and digging, at 2s. per ton.	Labour in working, at 2s. 6d. per ton.	Labour in making, at 1s. per ton.	Cost of coals, at 20s. per ton.	Double duty.	Extra for management, kiln-rent, waste labour, packing, and taking out of the kiln, and contingencies.	Total cost per 1000 feet in the kiln.
	tons cwt. lbs.	cwt. lbs.	£. s. d.	£. s. d.	s. d.	s. d.	s. d.	s. d.	£. s. d.
4 by 4	6 13 0	6 73	0 13 4	0 16 7½	6 8	6 8	10 6	9 4¾	3 3 2½
5 .. 5	7 15 2	7 85	0 15 6¼	0 19 5	7 9¼	7 9¼	10 6	10 11	3 11 10¾
6 .. 6	8 18 6	8 104	0 17 10	1 2 4	8 10½	8 10½	10 6	12 6	4 0 11
8 .. 8	12 19 3	12 54	1 4 11	1 11 2	12 5¾	12 5¾	10 6	17 4¾	5 8 11¼

81. Will you give a tabular return of the comparative cost of solid brickwork and of hollow brickwork per superficial yard?—

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TABLE contrasting the PRICES of SOLID BRICKWORK at the contract price under the Commission, namely, 11*l*. per rod, with Brickwork of Hollow Bricks, if made by contract under the Commission, including the duty in both cases.

Description of Labour, Materials, &c.	Quantities.	9-inch solid brick-work, laid in mortar.	8-inch hollow brick-work, laid in mortar.	Gain by using 8-inch hollow instead of 9-inch solid brick-work.
		s. d.	s. d.	s. d.
Bricks	Per sq. yard.	2 10¼	..	..
Labour, Carriage, &c.	,,	1 2	0 8	..
Mortar	,,	0 10	0 6	..
Cost of hollow bricks, if made by contract under the Commission	,,	..	1 5½	..
Total	,,	4 10¼	2 7½	2 2¾

Mr. Rawlinson prepared the following table of the relative cost of hollow and solid brickwork, and, having carefully considered it, I find it agree very nearly with my own experience :—(*See* p. 195.)

82. Are you aware of any experiments with respect to the comparative strength of these materials?—Such experiments have been made, and, as a general result, it is found that hollow bricks are one-third stronger than solid bricks of the ordinary size. The following table will show the degree of strength given to pipes subjected to the pressure before described as compared with unpressed pipes —

EXPERIMENTS to try the STRENGTH of PIPES made by the NEW MACHINE, March 2, 1849.

Number of Experiments.	Marks.	Bore of Pipe, in inches.	Thickness of Pipe, in inches.	Length of Pipe, in inches.	Weight of Pipe, in pounds.	Breaking Weight in pounds pressure per inch.	Altitude in feet.	Rolled or not.	Glazed or not.	Remarks.
1	H.	2·812	·469	20·68	8·75	420	970·2	Rolled	Unglazed	Smith's fine clay.
2	H.	2·87	·471	22·37	9·25	380	877·8	,,	,,	
3	H.	2·87	·471	22·37	9·25	280	646·8	,,	Glazed	
4	N.	2·68	·472	21·0	7·75	180	415·8	Unrolled	Unglazed	Smith's fine clay.
5	N.	2·7	·473	21·5	7·89	170	392·7	,,	,,	
6	N.	2·69	·471	21·3	7·9	200	462·0	,,	,,	
7	E.	2·75	·468	21·5	8·12	140	323·4	Rolled	,,	Smith's coarse clay.
8	A.	2·75	·468	22·31	8·25	270	623·7	,,	,,	
9	B.	2·75	·468	22·37	8·25	260	600·6	,,	,,	
10	M.	2·75	·5	21·37	8·25	160	369·6	Unrolled	Glazed	Smith's coarse clay.
11	M.	2·75	·468	21·37	8·5	120	277·2	,,	Unglazed	
12	M.	2·73	·475	21·47	8·36	110	254·1	,,	,,	
13	..	2·375	·656	23·12	12·25	660	1,524·6	Rolled	Glazed	Smith's fine clay
14	..	2·375	·656	22·75	12·25	360	831·6	,,	,,	
15	..	2·375	·630	24·12	12·75	500	115·5	,,	,,	

Averages of the above.

								Difference per Cent.	
1 to 3	2·8506	·470	21·806	9·083	360	831·6	Rolled	96·36	Fine clay.
4 to 6	2·69	·472	21·26	7·846	183·3	423·5	Unrolled		
7 to 9	2·75	·468	22·06	8·206	223·3	515·9	Rolled	71·79	Coarse clay.
10 to 12	2·743	·481	21·403	8·37	130	300·3	Unrolled		
13 to 15	2·375	·6473	23·33	12·416	506·6	1,170·4	Rolled	..	Fine clay.

Mr. Gotto.

ANALYSIS of the CUBIC CONTENTS, AREA, HEIGHT, and COST PRICE of HOLLOW TILE and SOLID BRICK.

No.	Description of Materials.	Thickness of Tile in section.	Dimensions of Common and Hollow Bricks. Inches. Length.	Breadth.	Thickness.	Relative cost per thousand.	Number of bricks in one square yard.	Number of square yards in one thousand.	Thickness of Wall in inches.	Net cost of Bricks in one square yard.	Cost of Labour to set one square yard.	Cost of Mortar to set on square yard.	Cost of one square yard set complete.	Remarks.	Extra cost per yard if set in cement.	Cost of one square yard set complete in cement.	Cube inches of space in one square yard.	Cube inches of solid in one square yard.	Weight in lbs. of one Brick.	Weight of one thousand solid and hollow bricks.	Weight in lbs. of one square yard.
		In.				£. s.				s. d.	d.	d.	s. d.		d.	s. d.				T. c. q. lb.	
1	Common brick .	..	9	4½	3	1 10	96	10½	9	2 10¼	9	9	4 4¼	Wall one brick, or 9 in. thick .	9	5 1¼	..	11,664	8½	3 15 3 16	816
2	Common brick for partitions. . .	..	9	4½	3	1 10	48	21	4½	1 5	5	5	2 3	Wall one brick, or 9 in. thick .	5	2 8	..	5,832	8½	3 15 3 16	408
3	Hollow brick, square on section	1	12	9	9	5 15	12	83⅓	9	1 4½	8	6	2 6¼	Wall half-brick, or 4½ in. thick.	6	2 8	7,056	4,608	27¼	12 3 1 6	327
4	Hollow ditto . .	1	12	8	8	4 15	13½	74	8	1 3½	8	6	2 5½	Wall one hollow brick, or 9 in. thick. . . .	6	2 6½	5,832	4,536	23	10 5 1 12	310½
5	Ditto	¾	12	6	6	3 10	18	55⅔	6	1 3¼	8	6	2 5¼	Wall one hollow brick, or 8 in. thick. . . .	7	2 1½	4,320	3,456	14	6 5 0 0	252
6	Ditto	¾	12	5	5	3 0	21¾	47½	5	1 3	8	6	2 5	Wall one hollow brick, or 6 in. thick. . . .	8	2 5	3,132	3,348	10¾	4 15 3 26	233¾
7	Ditto	¾	12	4	4	2 5	27	37	4	1 2½	8	6	2 4½	Wall one hollow brick, or 5 in. thick. . . .	9	2 10	1,944	3,240	7½	3 6 3 24	202
8	Hollow ditto partition tile set on edge	½	12	6	2	1 10	18	55⅔	2	0 6½	4	2	1 0½	Wall one hollow brick, or 4 in. thick. . . .	4	1 4½	864	1,728	7	3 2 2 0	126

N.B. One square foot of tile one inch thick is taken at 10lbs. weight.

[2.]

Mr. Gotto. COMPARATIVE STRENGTH of MATERIAL on each square Inch of the Sectional Area of Pipes.

Bore of Pipe, in inches.	Thickness of Pipe, in inches.	Sectional Area of Pipes.	Breaking Weight in pounds on each square inch of the Sectional Area.	Altitude in feet on each square inch of the Sectional Area.	Rolled or not.	Remarks.
2·8506	·470	4·903	73·41	169·6	Rolled	Fine clay.
2·69	·472	4·688	39·2	90·41	Unrolled	
2·75	·468	4·732	47·2	109·07	Rolled	Coarse clay.
2·743	·481	4·872	26·7	61·61	Unrolled	
2·375	·6473	6·146	82·5	190·6	Rolled	Fine clay.

EXPERIMENTS to try the STRENGTH of RED EARTHENWARE PIPES made by the PATENT PIPE MACHINE, July 18, 1849.

Number of Experiments.	Mark.	Bore of Pipe, in inches.	Thickness of Pipe, in inches.	Length of Pipe, in inches.	Weight of Pipe, in pounds.	Breaking Weight in pounds pressure per inch.	Altitude in feet.	Rolled or not.	Remarks.
1	A.	2·75	·5	23·125	7·437	175	404·25	Rolled	Sound to 120 lbs.; then the water came through in several places.
2	,,	2·75	·5	22·312	6·875	135	311·85	,,	
3	,,	2·625	·5	20·375	6·25	110	254·10	Unrolled	Sound to 100 lbs., and then same as No. 1.
4	,,	2·687	·5	20·5	6·25	Unsound	..	,,	
5	B.	2·687	·5	23·5	7·5	105	242·55	Rolled	
6	,,	2·687	·5	22·25	7·25	Unsound	..	,,	
7	,,	2·625	·5	21·187	6·624	95	219·45	Unrolled	
8	,,	2·625	·5	17·562	5·5	50	115·50	,,	
9	C.	2·812	·5	23·25	6·562	185	427·35	Rolled	
10	,,	2·625	·5	21·5	6·062	155	358·05	Unrolled	
11	D.	2·75	·5	23·875	7·624	125	288·75	Rolled	
12	,,	2·687	·5	23·687	7·624	120	277·20	,,	
13	,,	2·687	·5	21·625	6·875	95	219·45	Unrolled	
14	,,	2·562	·5	21·25	6·562	100	231	,,	

Averages of the above Pipes, &c.

A.	2·75	·5	22·719	7·156	155	358·05	Rolled	40·9 difference per cent.
,,	2·656	·5	20·437	6·25	110	254·10	Unrolled	
B.	2·687	·5	22·87	7·375	105	242·55	Rolled	38·9 ,,
,,	2·625	·5	19·37	6·062	77·5	167·47	Unrolled	
C.	2·812	·5	23·25	6·562	185	427·35	Rolled	19·3 ,,
,,	2·625	·5	21·5	6·062	155	358·05	Unrolled	
D.	2·718	·5	23·78	7·624	122·5	282·97	Rolled	25·6 ,,
,,	2·624	·5	21·5	6·718	97·5	225·22	Unrolled	

Mr. Gott

COMPARATIVE STRENGTH of MATERIAL on each square Inch of the Sectional Area of Pipes, July 18, 1849.

Bore of Pipe, in inches.	Thickness of Pipe, in inches.	Sectional Area of Pipes.	Breaking Weight in pounds on each square inch of the Sectional Area of Pipes.	Altitude in feet on each square inch of the Sectional Area of Pipes.	Rolled or not.
2·75	·5	5·105	30·3	70·1	Rolled.
2·656	·5	5·	22·	50·82	Unrolled.
2·687	·5	5·007	20·9	48·4	Rolled.
2·625	·5	4·9	15·8	34·2	Unrolled.
2·812	·5	5·203	35·5	82·1	Rolled.
2·625	·5	4·9	31·6	73·	Unrolled.
2·718	·5	5·1	24·	55·4	Rolled.
2·624	·5	4·8	20·3	46·9	Unrolled.

83. Were not experiments directed to be made as to the strength of hollow bricks of different kinds?—They were; but various circumstances have prevented me completing those experiments in detail.

84. Were there not experiments directed to be made as to the comparative flow of water through pipes made more exact by compression?—They were, and the result showed that the rolling or pressure gave one quarter more velocity to the water.

HYDRAULIC EXPERIMENT, showing the delivery of Water through red unglazed Pipes, compared with glazed stoneware.

Description of Pipe.	Inclination.	Time to discharge 25 Cubic Feet.	Height of Water above Top of Pipe.	Diameter of Pipe.	Cubic Feet per Hour.	Velocity per Second.	Stoneware compared with the Red Pipe.
		m. s.	Inches.	Ft. In.		Feet.	
Glazed stoneware .	1 in 60	2 0	3	0·24	750·	4·9	..
Red-ware rolled, B.	,,	2 18	3	0·23	652·17	3·72	5 to 4·34
Red-ware, B. . .	,,	2 48	3	0·23	535·71	3·06	5 to 3·57
Red-ware rolled, D.	,,	2 28	3	0·23	608·1	3·47	5 to 4·
Red-ware, D. . .	,,	2 46	3	0·23	542·1	..	5 to 3·61

The Pipe in the above experiment was fully charged.

EXPERIMENTS with the same Pipe running half full.

Glazed pipe . .	1 in 60	4 16	Water level with head of pipe	..	351		
Red-ware rolled, B.	,,	5 58	,,	..	251	..	5 to 3·52
Red-ware, B. . .	,,	6 34	,,	..	228	..	5 to 3·24
Red-ware rolled, D.	,,	6 15	,,	..	238	..	5 to 3·39
Red-ware, D. . .	,,	7 15	,,	..	206	..	5 to 2·93

85. From this evidence it appears, then, that by these means an increase of velocity of one-fourth may be given to the general sweep of water and the rate of discharge of all fæcal matters from beneath the site of towns?—Yes, that is so.

Mr. Gotto. 86. What would be the price per foot of 4-inch pipes of the improved manufacture (with compression)?—Four-inch red earthenware pipe could be manufactured in large quantities for about 1½*d.* or 2*d.* per foot.

87. Will you give any points of information you possess as to the run of water through drains or sewers in the district of the East London Company on the days when the water is laid on as compared with the days when the water is not laid on?—I have not had an opportunity of furnishing this information.

Mr. John Morris, examined.

Mr. Morris. 1. What position do you hold?—I am surveyor of highways of the parish of Poplar, and hold an appointment under the Metropolitan Commission of Sewers.

2. The Metropolitan Sanitary Commissioners are desirous of ascertaining what extra quantity of water will be required beyond the common supplies for house-drainage under the improved system. Have you not within your district a block of houses which has been drained with tubular drains?—Yes; between 20 and 30 blocks of houses.

3. Will you give a specimen of one?—Yes; there is a block of 12 houses which has been drained with 4-inch glazed pipes leading to a 6-inch drain in the road. These houses are supplied by the East London Water-works, on the intermittent system, and the drains have been 12 months in action.

4. Have you the opportunity of seeing that they discharge all matter coming into them by the ordinary quantity of soil-water so as to keep the drains quite clean?—Yes; and yet the water is only thrown into the soil-pans not regularly laid down, so that they are under that disadvantage, and still they answer, although one of the drains was stopped for want of water.

5. Has each house a soil-pan apparatus?—Soil-pan and trap, but still it is imperfect, inasmuch as the water has to be thrown down, and where water has to be taken to it it does not get attended to.

6. Is this common drain laid under the road?—Yes; a 6-inch drain was laid down under my direction in the road, and has acted perfectly.

7. Under the old method would there not have been a brick drain carried through the house?—Yes; there would have been a 9-inch brick drain, and that would inevitably have been stopped. In a house of my own a brick drain has been twice cleansed in the course of seven years, and I have just laid down a tubular drain instead of it, as I found the water was settling under the foundation of the house.

8. Then a 9-inch drain, which was required by the Building Act, would inevitably have been stopped up, while the improved kind with the same supply of water kept clear?—I may observe as respects the old brick drains that the smell is so bad in some houses that the doors and windows were compelled to be opened in consequence of the brick drains being under the floors.

9. Have you tried these new 4-inch tubular house-drains, laid down and kept in action in your district for such a time and under such varied

circumstances as to leave you no doubt of their applicability to all the drainage within it?—I have introduced them into some houses for the trustees of the parish of Poplar, with water-closets, and have received no just cause of complaint. In every instance where I have applied it I found the system answer extremely well where a sufficient quantity of water has been applied. Mr. Morris

10. What are the expressions of the occupiers in relation to the new tubular drainage?—Expressions of great satisfaction: they have now no smells on the premises, and that they feel better in health.

11. In the particular block of houses you mentioned, what would be the expense of draining from six houses by one 4-inch pipe, as compared with the prices of draining laid down upon the old method? —About two-thirds less.

12. And there is the saving of not only the length required for carrying the drain through the front of the house to the centre of the street, but also a saving in the distributory apparatus for the water?—Yes.

13. Then this double plan just exhibits the different modes of drainage under the old system and that of the Metropolitan Sewers Commission. Can you describe the sanitary effects of this improved drainage? —There is no comparison between them; so decided is the advantage of the improved method, as before stated.

14. What are the observations of the householders as to the effect of the new drainage?—The answer has invariably been; that they and their families have been better in health; that they were formerly annoyed with smells and effluvia, from which they are now quite free.

15. Of course access to the backs of the premises for the repair of the drains or the service pipes for the distribution of water would be sometimes required. Have you experienced anything that would suggest to your mind that obstacles would be placed in the way of carrying out the system of drainage requiring such access?—I think not now, though there would have been formerly, the public not having had the experience of the improvement. I now think the public are prepared to go with the authorities in carrying out a complete system of back drainage.

16. Since the new drainage has been laid down has there been frequent occasion to go on the ground to examine it?—In this case there has been only occasion to go to it once for the whole year, and that was from the inefficiency of the water service.

17. And the whole district might then have been drained in the same way with as little relative demand for the inspection of back premises? —Yes, certainly. In one instance examination was requisite, and it was there found that rags had been thrown down and had got into the pipe, and further that very little water had been used, so that the stoppage was the fault of the tenant, not of the system. In this case the rain-water is carried away by a separate drain.

18. Have you considered what would be the advantage of a constant supply of water to these soil-pans?—Yes. It would in my opinion be a saving of one half the water, and the soil-pans and drains under the improved system be less liable to stoppage. I have found it answer very well where it has been applied to some of the water-closets.

19. Even supposing that there were no improvement in the population

Mr. Morris. themselves nor in their habits, judging from the practical experience now obtained, would the occasional stoppages and obstructions resulting from carelessness or willingness, countervail the advantages of the system?—Certainly not. It has been applied to houses in Bromley St. Leonards. The inhabitants were poor Irish people, and not prepared by their habits for such improvements, but the plan answers, although the supply of water is very ill applied.

20. What sized butts are usually used for this poor class of houses?—4 feet by 2 or thereabouts, holding about 54 gallons.

21. From what you have observed of the population, do you think they use the whole of the contents of such a butt each day?—I think not so much.

22. Then if there were a constant supply of water carried into each house, there would not be more than 40 or 50 gallons used each day?—I think not.

23. It is stated that in the district about 200 gallons per house is pumped in three times a-week. Does it not follow from your statement of the sizes of the butts and the quantities consumed, that the greater proportion of the water now pumped into the district must be pumped to waste?—Yes; quite one half: all parties coincide in saying that full one half is now wasted.

24. Then you think that no additional quantity of water will be required in your district?—Not to the houses already supplied. All that is required is a different mode of application.

25. I believe there is very little paving in your district?—No; water would not be required for surface-cleansing, only for road-watering.

26. What amount of water do you use for that purpose?—28,000 gallons daily for the last season, which was 75 days, over a space of 50,000 yards, supplied at a cost of 5*s.* 6*d.* per 100 yards for the season, six months.

27. What is the largest single block of houses in your district drained by tubular drains?—150 houses, through a 6-inch earthenware outfall pipe not glazed.

28. Do all the houses drain into it?—They do; the drains are all old drains. The 150 houses drain into it, and about 10 of them have water-closets.

29. How is this earthenware pipe laid down?—It was laid down without any care, and connected with a 14-inch drain from the houses, and when it was accidentally stopped, from the pipe having broken, it was found that this drain had been in use for 17 years. All the drainage of this large block of houses must have been gradually carried into it in the course of years.

30. What is the quality of the water supplied by the Company in your district?—It is hard, and a sediment is produced in the cisterns; 2 or 3 inches of deposit collect in the course of a short time.

31. What do you pay for this supply?—About 4*s.* per room, and for a 3 or 4 roomed house about 3*s.* 6*d.* a room.

32. Supposing the water were properly distributed, would any additional supply be required?—I think not for the East of London.

33. Have you noticed the effect of these permeable drains when there is no rainfall?—I have seen the water under the basement-floors of houses, arising partly of the waste of the water pumped in.

34. Therefore the waste at present is worse than useless?—Yes; for it only creates dampness in the yards and houses. Mr. Morris.

35. Will you give the contrast in prices of the construction of new impermeable drainage with the permeable drainage, and contrast that with what it will be before the change of system?—I applied some years since to the old Sewers Commission to drain a district in the Tower Hamlets, and for main drains alone for some 600 or 700 houses they asked 4000*l.*; that would have been at a rate of charge, with the private drains, altogether, of nearly 10*l.* a house; under the present system not only could the main drains be made, but the private impermeable drains also, complete, at 5*l.* a house.

36. By the new system is not the smell from the drains prevented in houses?—Yes; I have inquired of the tenants of the house where the drains have been reconstructed under the new system, and they inform me the smell is abated.

37. Then you agree with other surveyors as to the best observations which have been made with regard to the waste of water?—They coincide precisely with my own views.

38. Do you think that as much water as 200 gallons per house can be required, even where a portion of the water would be needed for water-closets or for road-watering?—I think not.

39. Then you concur in the opinions expressed upon these points by other assistant surveyors, that if the water pumped in were properly distributed under a system of constant supply, properly applied to an appropriate system of tubular drains, no additional quantities would be needed either for domestic use, or for the flushing of drains or sewers, or for road-watering?—The present quantity would certainly be ample.

Mr. J. Medworth examined. Mr. Medworth.

Have you not been engaged in carrying out experimental trial-works under the Metropolitan Commission of Sewers?—I have.

Among other trials have you tried the quantity of water requisite for soilpans of different forms and constructions?—I have.

What is the least quantity of water required to carry away the soil from, and keep clear, a syphon-pan as at present constructed?—I have found a gallon on an average sufficient.

How much more is required for pans of other construction?—Sometimes, even with repeated flushes, there was a difficulty in keeping them clear, but it mainly depended on the way in which the water was admitted to the inner surface of the pan.

Then, with any quantity, some pans will not keep themselves clean?—In some pans, as constructed, it would require a very large amount of water to ensure a perfect clearance of the contents.

You have seen that the syphon-pans will keep themselves clean?—Yes: those of the commonest description—those made of brown stoneware.

Will you put in a diagram of the same?—This form of basin I have found to be the best kind, where there is no pan or dish used.

Mr. Medworth.

Have you not reason to believe that the form and application of the jet are still capable of improvement even for the action of the syphon-pan ?—Yes.

Would it not be better to admit the water in the front ?—I think not. There is soil to be removed from the back of the basin, which would not be reached by the water if admitted in the front.

You think further experiments necessary for the proper adjustment of this ?—Certainly. I think that the closet experiments at Greek-street were not carried out sufficiently, but I am satisfied that a gallon of water would suffice.

Then in a family of five persons 5, 6, or 7, or 10 gallons at most, would certainly be sufficient ?—Certainly; particularly taking into consideration the quantity of slops that would be thrown down.

But is not the escape of gas more frequent from other pans than from the syphon-pan, as stated by Mr. Crump, of Derby ?—Generally so.

But they require less water ?—They do; half that is required for the syphon would be sufficient for the pan-closet.

Of course you would support the syphon-pan as most fitted for popular use ?—Certainly; in consequence of the simplicity of the arrangements.

Both for cheapness and completeness ?—Yes; except that in the syphon-pan arrangement there is a larger expenditure of water.

Among other things, were you not directed to try the flow of water from pipes of different constructions—some formed with pressure and some formed in the common way ?—I was.

Did you not find that making the pipes smooth in the interior gave an increase of velocity of a third or fourth through a 3-inch pipe ?—I did. These experiments were made with red-ware pipes, smooth, but not glazed.

What quantity of water would be discharged through a 3-inch pipe on an inclination of 1 in 120 ?—Full at the head, it would discharge 100 gallons in three minutes, the pipe being 50 feet in length. This is with stone-ware pipe, manufactured at Lambeth. This applies to a pipe receiving water only at the inlet, the water not being higher than the head of the pipe.

What would be the rate of discharge supposing the whole 100 gallons to pass through the drain from the back to the front of the house, say some 60 feet, and how soon would the water be clear of the premises ?—All that could be swept away by 100 gallons would be discharged clear of the house at the rate I have already stated.

What would be the power of sweep ?—Sufficient to remove any and even more than ordinary and usual semi-fluid deposit that is found in house-drains; that is, supposing the whole of the 100 gallons was to be discharged in the time stated.

What water was this ?—Sewage-water, of the full consistency, and it was discharged so completely, that the pipe was perfectly clean.

At the same inclination what would a 4-inch pipe discharge with the same distances ?—Twice the amount (that I found from experiment); or, in other words, 100 gallons would be discharged in half the time. This likewise applies to a pipe receiving water only at the inlet, and of not greater height than the head. In these cases the section of the stream is diminished to about half the area of the pipe.

Then a 4-inch pipe will discharge a 24 hours' supply of sewage-water a distance of 50 feet in a minute and a half?—Yes; taking the 24 hours' supply to be 100 gallons.

Did you not try the force of this discharge with sand? and, if so, with what proportions?—Yes, with sand in proportion of from 1-16th to 1-40th the volume of the water, and the whole was entirely removed.

But the different construction of the pipe with respect to smoothness will make full a fourth difference in the rate of velocity?—Yes; with the red-ware pipes formed by pressure, the accelerated velocity due to regularity of form and smoothness of surface was one-fourth.

What pipes did you use in these experiments?—In some experiments, including those previously referred to, we used red-ware pipes, but principally glazed stone-ware pipes were used in the experiments at Greek-street.

Have you not found that exactitude in the make is more important than the glaze?—Yes, the exactness of form and ACCURACY OF JOINT are very important, so that the pipes may run into each other and form a complete cylinder. As an instance of the importance of exactness of joint, I had a case happen at one of my houses within the last few days. The tenant complained of the stoppage of the drain from the closet, &c. Upon sending a man to make an examination, it was found that the trap contained several oyster-shells, and one had been discharging into the drain, where it was arrested by an imperfectly formed joint.

Then you found on experiment that this exactness of form expedited the discharge full one-fourth?—Yes. As before stated in the case of the red-ware pipes.

Have you tried the effect of junctions on the main?—Yes.

Suppose two of these 4-inch pipes were joined, what would be the velocity gained by junction into a main?—At an inclination of 1 in 60 the increased discharge would be in some cases nearly double; that is, the single pipe will deliver 84 gallons per minute; the addition of another similar 4-inch pipe will increase the discharge to 162 gallons per minute. The discharge will vary, dependent upon the position of the junction on the main line; the further from the head or inlet, the greater the discharge.

Before these experiments were made, were there not various hypothetical formulæ proposed for general use?—Yes.

What would these formulæ have given with a 3-inch pipe, and at an inclination of 1 in 100? and what was the result of your experiments with the 3-inch pipe?—The formulæ would give 7 cubic feet, the actual experiment gave 11½ cubic feet; converting it into time, the discharge according to the formulæ, compared with the discharge found by actual practice, would be as 2 to 3.

Or, putting it into another form, if there were a given quantity of detritus or fæces to be removed, it would, according to the formula, require nearly double the quantity of water that was found absolutely requisite in practice?—The proportionate discharges were found to be as 2 to 3, therefore the power required would be in those ratios.

How would it be with a 4-inch pipe?—The formula would give about 14·7 cubic feet per minute, whereas practice gave 23 cubic feet per minute.

Take the case of a 6-inch pipe of the same inclination?—The result,

Mr. Medworth. according to Mr. Hawkesley's formula, would be $40\frac{1}{4}$ cubic feet per minute; from experiment it was found to be $63\frac{1}{2}$ cubic feet per minute.

Will you convert that into time, and consider the 6-inch pipe as a small branch sewer? Within what time would 100 gallons be discharged at the same inclination over 50 feet?—It would be discharged in 15 seconds.

That is to say, that the actual experiments prove how much less water can be made to suffice than these formulæ prescribe?—Precisely so.

Then with respect to mains and drainage over a flat surface, the result of course becomes of much more value as the difference proved by actual practice increases with the diminution of the inclination?—Certainly, to a very great extent. For example, the tables give only 14·2 cubic feet per minute as the discharge from a pipe 6 inches diameter, with a fall of 1 in 800; practice shows that, under the same conditions, 47·2 cubic feet will be discharged.

Will you give an example of the practical value of this when it is required to carry out drainage works over a very flat surface?—An inclination of 1 in 800 gives only 14 cubic feet per minute according to theory, while, according to actual experiment, and with the same inclination, 47 cubic feet are given.

Then this difference may be converted either into a saving of water to effect the same object, or into power of water to remove feculent matter from beneath the site of any houses or town?—It may be so.

And also the power of small inclinations properly managed?—Yes. For example, if it was required to construct a water-course that should discharge say 200 cubic feet per minute, the formula would require an inclination of 1 in 60 = 2 inches in 10 feet; whereas experiment has shown that the same would be discharged at an inclination of 1 in 200, equal to $\frac{5}{8}$ths of an inch in 10 feet, thus effecting a considerable saving in excavation, or a smaller drain would suffice at the greater inclination. The practical importance of knowing the precise value of inclination is incalculable, and will be found so in laying down drainage for a flat district, or through loose and wet soils, where the extra labour in excavating the last few inches in depth to obtain a given level will often exceed in cost as many feet. I have frequently met with such cases. To name one, I will state that, during the progress of a sewer contract I had in 1842 for the Commissioners of the Holborn and Finsbury district, the depth of the trench was about 9 feet, and perfectly dry; the cost for labour was 8*d.* per cubic yard; the invert of the sewer, according to the levels given by the surveyor, required to be about 6 inches lower, and this proved to be in a running sand of the most troublesome nature, and cost me at the least 10*s.* per yard in the removal before the invert could be laid down.

Then all these experiments tended to the reduction of the quantity of water necessary to effect good cleaning, and removal of soil and matter held in suspension?—It would.

And render more manageable works of drainage with comparatively small power, and make it more efficient and much cheaper, with properly constructed machinery?—Yes.

Mr. Hawkesley's tables are, I believe, taken as embodying the current and most recent formulæ before the institution of the trial-works,

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and were in practical use by engineers, &c.?—They were of the highest authority; but the results I have given have been verified by a variety of experiments.

What junctions did you try?—A 3-inch junction into a 4-inch main, and a 3-inch junction into a 6-inch main.

Would it not have been the practice formerly in making a junction of two 3-inch pipes to have made the outlet a 6-inch pipe?—That, I believe, would have been the general practice.

Will you state what you have found the practical results of these trial-works to be on this subject?—One very important result arrived at is the fact of having ascertained the precise value due to *inclination*, as has been before shown. This was a point not practically known to writers upon hydraulics, if we may judge by the theories promulgated. Again, the *actual* practical discharge of water through pipes of different sizes has been determined upon, together with the effects that junctions on to a *main line* have. The system of projecting the results of the experiments by diagram suggests a ready method of calculating the discharge due from cylindrical water-courses. This has the authority of the late "Trial Works Committee," and is, I believe, recommended in their Report recently laid before the present Commissioners. These are a few amongst the many practical results obtained from the trial-works.

What are the practical deductions from these effects in respect to junctions?—The practical effect is a considerable degree of velocity in the discharge of water.

An increase of velocity in the discharge, and a diminution of water to effect the object?—Certainly.

Was it not a request from the Trial Works Committee to carry these experiments out further?—I believe it was.

Were they continued after the change in the Commission?—They ceased on the retirement of the late Commission; and a few days after the resignation of the consulting engineer I had directions to discontinue the experiments, and discharge the men employed on them.

By whose orders?—Those of the chief surveyor, Mr. Phillips.

At the highest ordinary storm rainfall, what extent of roof would a 3-inch pipe and 4-inch pipe respectively keep clear?—Taking the rainfall to be two inches in one hour, a 3-inch pipe, laid at an inclination of 1 in 60, would convey away the water from 47 squares of roofing = 4700 square feet; a 4-inch pipe under the same circumstances would carry off the rainfall from 98 squares of roofing = 9800 square feet.

The rate of house-drainage which it has been calculated can be removed in three minutes would of course be spread over the 12 hours?—Yes, over the day.

Consequently, for all purposes of soil-water, the size of drain might still further be reduced, and the flow of water required to keep them clear might be further economized?—Yes, as regards the sewage, but provision must be made for the passage of a certain amount of solid matter; therefore no drain should be *less* than *four inches* diameter.

Have you seen the 4-inch tubular pipes in various circumstances?—Yes; and I have found that they keep themselves clear; that is, where care has been taken in laying them down, and an uninterrupted outlet

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is provided; unless, through the carelessness of the occupier, substances that ought not to find their way into house-drains are thrown down the water-closet. A case of an obstructed house-drain occurred at one of my own houses within the last few days. The tenant complained that the water, &c., would not leave the closet and sinks. Upon making an examination by taking up the pan and trap, the latter was found to contain several *oyster-shells* (which certainly cannot be considered as legitimate deposit). One had been discharged into the drain, and was arrested by an irregular and imperfectly formed joint; it had thus become a nucleus for further obstruction, and ultimately by a piece of house-flannel, had permanently stopped the passage of the soil, &c. It is from such-like circumstances that prejudices arise against the adoption of a 4-inch drain. The above case would not cause me to alter my opinion as to the efficiency of a 4-inch drain.

Would a 3-inch pipe take more than the house-drainage?—Yes, considerably more *fluid* than belongs to the house; but I would not advise less than 4-inch tubes to be laid down for house-drains, as all the experiments tried seem to be in favour of a 4-inch pipe. In the 3-inch pipe the area is too confined to pass solids, such as large pieces of paper, &c.; and in a 6-inch pipe the water is spread over too extended an area. After four inches the area of friction increases so rapidly as to make it inexpedient to use larger pipes.

Taking a house-drain and its junctions, will you state within what time water discharged through it would get beyond the three-mile radius from the Post-Office, calculating with ordinary falls and levels, and the usual rate of discharge?—Suppose the house-drain to be of non-absorbent stoneware, the soil and slops from a house would leave the premises as fast as made; this, delivered into a main line of the same material and 12 inches diameter, laid with a fall of 1 in 240, and running full, would deliver the house-drainage beyond the limits specified in 45 minutes, the velocity of the stream in the main line being about four miles per hour.

Since by back-drainage you save two-thirds of the distance of discharge on an average, you increase the power as respects the velocity and friction?—Yes.

And you gain in that way in any escape that might otherwise occur of any of the gas from the decomposing matter?—Yes; in a well-constructed drain of stoneware no substances would remain to become decomposed.

With a system of tubular drainage where nothing is allowed to remain to decompose, a total alteration in respect to the smells and nuisances from such a source may, of course, then, be expected?—Certainly.

It has been stated that, in the case of new blocks of houses where tubular drains have been laid down, no offensive smells are found to exist; does that agree with your experience?—It does, where sufficient care is taken in the construction, and there is a supply of water to remove the contents.

Have you made any other experiments than those contained in the Trial Works Report?—Yes; the experiments in the King's Scholars' Pond Sewer were made by me. The tables and diagrams that I now submit to the Board are deductions and calculations made by me from those experiments.

Did you in those experiments register the velocity per second of the water?—Yes; by timing a floating body of nearly the same specific gravity as the water. Mr. Medworth.

Did you measure the velocity at the bottom or middle, as well as that of the surface?—No.

What is the hydraulic mean depth of a 3-inch, 4-inch, 6-inch, and 9-inch pipe respectively, when half-full?—The hydraulic mean depth in the 3-inch pipe is ·749, in the 4-inch pipe 1·, in the 6-inch pipe 1·5, in the 9-inch pipe 2·18 inches.

What is the amount of friction to be ascribed to those pipes respectively?—The frictional line, or line in contact with the water, when the pipes are half full would be—in the 3-inch pipe 4·71, in the 4-inch pipe 6·28, in the 6-inch pipe 9·42, in the 9-inch pipe 14·13 inches.

What must be the major and minor axes of an ellipse which shall give an equivalent hydraulic depth to that of a 3-inch, 4-inch, 6-inch, and 9-inch pipe?—

Drains, inches in diameter.	Axes of Ellipse.	
	Major. Inches.	Minor. Inches.
3	3·6	2·5
4	4·6	3·5
6	6·8	5·3
9	10·4	7·8

What amount of friction would be due to each of those elliptical sections?

In the 3-inch pipe	9·74	inches nearly.
,, 4-inch ,, ...	12·85	
,, 6-inch ,, ...	19·13	
,, 9-inch ,, ...	28·9	

Did you make any experiments on the flow of water in egg-shaped pipes?—No.

Can you institute any comparison between egg-shaped and circular drains, using, as a term of comparison, either "time of discharge," "quantity discharged," "friction," or "velocity?"—Not from actual experiment.

Have you any explanation to offer on the phenomena marked in page 6 of the Trial Works Report, relative to the power of transport of a gallon of water through a 3, 4, and 6 inch pipe?—This and other questions having reference to the opinions or statements contained in the "Trial Works Report," I do not think I should be justified in offering any remarks upon, as, in my capacity as Superintendent to the "Trial Works Committee," I was only engaged in *making* the *experiments*, *calculating quantities*, and *projecting* the *diagrams*. The deductions from these and the Report itself exclusively belongs to the "Trial Works Committee," who framed that Report.

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Were the pipes of the same length, inclination, charged with the same head of water, and was the velocity at the exit equal?—They were equal in length, inclination, and charged with the same quantity —1 gallon of water; the velocity was not equal, being dependent upon the resistance offered by the deposit.

Supposing the impediment to be removed equal in weight, what head of water would be required for a 3, 4, and 6 inch pipe respectively?—Experiments would be required to determine the point involved in this question.

To what velocity does that level correspond; that is to say, supposing no impediment to exist, what would be the velocity of the fluid at its exit from each pipe charged with those heads of water respectively?—No experiments have been tried which will enable me to speak to this point.

Did you find the power of transport of a cube foot of water in a 3, 4, or 6 inch pipe bore the same ratio, supposing the inclination to vary? Or did this phenomenon occur only at one particular inclination?—It was only tried at one inclination. A reference to the diagram No. 2 will show the arrangement of this experiment.

How did you explain the remarkable fact then; an inclination beyond 1 in 60 offers far less advantage than has been commonly attributed to it?—I should be unwilling to offer an opinion upon this fact, as it has been specially noticed by the Trial Works Committee, though not explained by them.

Have you the results deduced from the experiments in the Fleet Sewer?—I have not.

Did you find the length of the tube made any difference in the velocity?—In very many of the experiments at Greek-street I noted the time that a floating body was passing half the length of the tube (50 feet), and again at the end; but the total length (100 feet) was not sufficient to enable me to perceive any appreciable difference.

At page 20 you have given an ideal section of the flow in a pipe; have you any such sections from actual observation?—The papers Nos. 6 and 1 contain various diagrams showing the sections of the flow in pipes of different areas, and under varying conditions. The sections I now hand in are from actual observations; nearly all the experiments I made can be projected in the like manner.

You say that each tributary adds something to the velocity of the main, yet the addition is gradually less; what ratio does the *decrease* follow?—The ratio of increase or decrease is dependent upon the inclination, also upon the position of the tributaries on the main line. Referring to the case of a line of pipes of 4 inches diameter, laid at an inclination of 1 in 240, with junctions each 3 inches diameter, it will be seen by the subjoined table (page 209), that the velocity due to the main stream is but little altered by the addition of No. 1 Junction (the section is *increased*, and, consequently, the discharge). But upon the introduction of two junctions the main line becomes filled, and the velocity is decreased one-third; from this point the decrease gradually becomes less, but to what extent the experiments did not reach.

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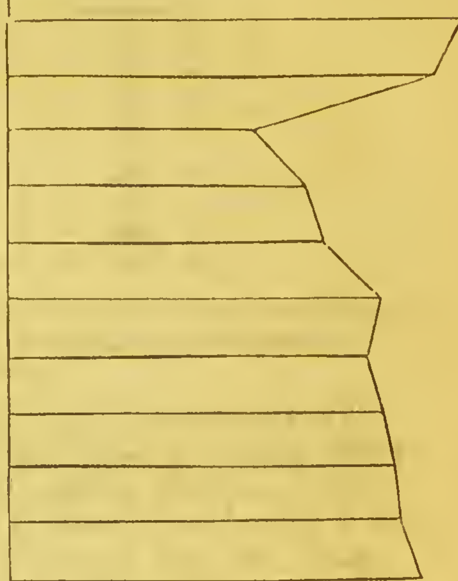
Table showing the Velocities; the Sectional Areas; and the Discharges of the Flow through a Main Line of Pipes 4 inches diameter by the introduction of Tributaries, each 3 inches diameter, and running in the following order:—

Main Line and Junctions.	Distance of Junctions from Head of Main Line.	Mean Velocity in Feet per Second.	Section in Inches.	Discharge in Cubic Feet.	Diagram illustrating Velocity.
	Feet.				
Main Line.	..	3·5	..	9·3	
1. Junction.	5	3·3	0·58	9·67	
2. Do.	25	1·9	6·56	10·16	
3. Do.	45	2·3	6·56	12·17	
4. Do.	65	2·5	6·56	13·33	
5. Do.	85	2·9	6·56	15·47	
6. Do.	10	2·8	6·56	14·93	
7. Do.	30	2·9	6·56	15·39	
8. Do.	50	3·05	6·56	15·8	
9. Do.	70	3·09	6·56	16·15	
10. Do.	90	3·2	6·56	17·12	



At what point would the water be dammed up in the tributary channels by the rapidly flowing water in the main, that is, after how many junctions had been made?—An inspection of the diagrams Nos. 3, 4, 5, will in some measure illustrate this question; it would appear that at an inclination of 1 in 240 before the introduction of any junctions, the water is backed up in the junctions, owing to the flow in the main line. There is no experiment to show the point at which the water would be dammed up in the tributary channels by the water in the main.

You have found the present experiments too restricted to ascertain the limits of velocity and distance; will you favour the Board with an idea of the scale on which you would require to try these experiments, in order to acquire sufficient data to enable you to lay down a theory on this subject?—The experiments have been far too restricted to enable any theory to be laid down on the subject; they would require to be made with pipes and channels of various forms, of large dimensions, and various lengths.

What, approximatively, judging from past experience, would be the cost of such a series of experiments?—The cost can only be ascertained from knowing to what extent the late Committee would consider it necessary to carry them.

The table, page 26, gives the increased discharge for each additional junction; what was the difference of velocity at the outlet when 1, 2, 3—10 junctions were added?—I have no sections of these experiments of this size from which I can calculate the velocities but

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the following, from experiments with the 4-inch pipes, which will give some idea of the principle of increase :—

MAIN LINE 100 feet in Length, 4 inches Diameter; the Junctions on to Main Line 3 inches each Diameter; Inclination 1 in 10.

Main and Number of Junction.	Distance of Junctions from Head of Main Influent.	Mean Velocity in Feet per Second.
	Feet.	
Main. . . .	. . .	8
1. Junction.	5	9
2. Do.	25	10
3. Do.	45	12
4. Do.	65	9
5. Do.	85	10
*6. Do.	10	8
7. Do.	30	8
8. Do.	50	9
9. Do.	70	11
10. Do.	90	12

* A reference to the position of the junction on the main line will explain the cause of the diminution.

Was the velocity of the influent constant or variable?—Constant, if by the question is meant the head of water at the influent.

Was it constant among all the influents of the same system?—Constant, if the head of water at the inlets is meant.

Have you seen an article in the 'Mechanics' Magazine' for 9th December, 1849, signed J. L. Hale?—I have; it was pointed out to me at the time. The *deductions* and *calculations* are my own, and were submitted by me to Mr. Hale (in his capacity as an officer of the Commission) for his opinion, and for the purpose of checking the calculations, as it was my intention (at that time) to lay the same before the Court.

Is the statement correct that the squares of the discharge are as the fifth powers of the diameter; and that in inclinations greater than 1 in 70 the discharges are as the square roots of the inclinations?—The calculation that I made at the time was, that the discharges of pipes of different diameters vary as the square root of the quotient of the fifth power of the greater diameter, divided by the fifth power of the lesser diameter, multiplied by the known discharge of the smaller pipe. The ratio of discharge due to greater inclinations than 1 in 70 is as the square root of the inclination. These deductions I arrived at from and after a careful investigation of the results found by the experiments. Mr. Hale, writing without data before him, is in error in respect to the "simple head of 22 inches" giving the same result as that "accruing under the circumstances of the junctions," as is shown by the diagram of the discharge through a 6-inch pipe, with increasing heads: about 14 inches head (above the centre of the pipe) will give an equivalent result. It is in the case of a 4-inch pipe that a "head of 22 inches" has been found to correspond with the results from junctions.

Will you throw some of your results into a tabular form, illustrating by the method of ordinates and abscissæ the results set forth in Mr. Hale's paper?—The diagrams now produced are copies of the original ones projected by me. (See No. 1.)

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Have you made any experiments on the influence of material of the pipes in accelerating or retarding the flow?—A partial experiment was tried at Greek-street; the pipes used were red ware and glazed stoneware, each 3 inches diameter. The velocity was much greater in the glazed stoneware pipes.

Did you register atmospheric temperatures and pressures during your experiments?—I did not.

Was the same watch employed throughout all the experiments?—It was.

Was it day by day compared with a standard regulator?—No.

Can you indicate any disturbing forces as probable causes of error in any of your experiments?—Whenever any material discrepancy occurred it would be in consequence of the difficulty in maintaining the precise head of water at the inlet. In all such cases the observations were carefully repeated.

Have you any remarks to offer on the general character of your experiments?—I consider them to be practically correct. Nothing approaching to mathematical accuracy could of course be expected to be arrived at in this series of experiments, but I consider they will supply sufficient data (as far as they go) for all practical purposes.

What further experiments do you think it would be desirable to make?—Full experiments were tried with pipes ranging only up to 6 inches diameter, and partially, only, with pipes ranging from 6 to 12 inches diameter. It would be exceedingly desirable that these experiments should be extended up to the very largest sizes, and varied in every possible way, so that safe and practical rules might be arrived at for the larger classes of sewers, without having to resort to formulæ based upon the result of experiments with tubes of small diameter.

Will you furnish the Board with drawings of your apparatus and account of the cost of the whole detail?—The cost of the experiments I have no means of ascertaining; the secretary alone can answer this the question.

You have observed the action of small 4-inch tubular house-drains; do you find it necessary in practice, for cleanliness and efficiency, to keep such drains constantly running, or flushed out at frequent periods, to prevent the hardening of deposit? Have you found any tendency to deposit in them with the present supply of water?—I have in numerous cases observed small tubular drains which have acted and continue to act perfectly, with the ordinary supply of water. I have not found that the water is required constantly to run through them, or that they require frequently flushing. There is no tendency to deposit in them, the ordinary supply of water keeping them perfectly clean. In these cases there was *a free outlet*, the tubes were *properly* laid down, and no *impediment* at the *joints*. I would further remark that, upon all occasions where I have been able to investigate the cause of obstruction in a small drain, I have invariably found it to proceed from substances such as shells, broken earthenware, sticks, &c., becoming fixed at the sock-joints; this soon forms a complete dam across the tube, and the drain is choked; and no ordinary power or quantity of water that could be sent down by flushing would be sufficiently effective to remove the compact mass; the only method to relieve it is by breaking up the drain. I would strongly recommend the use of pipes conical at the end, the *end* of the one pipe

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going into the *head* of the *other*; here the liability of stoppage is all but impossible.

Take the case of a large brick drain at the same inclination as the small tubular drain, what do you find in practice?—In the large brick drain I find as the result deposit constantly accumulating, which the ordinary supplies of water are wholly inadequate to prevent. The water that does not escape through the open or imperfectly made joints of the brickwork is rendered almost inoperative by being spread over a large area.

Then the inference is, that with the present supply of water the small tubular drain would be self-acting, and that the large brick drain would require a constant flushing power to remove the accumulated deposit?—Yes, such would undoubtedly be the case; as the house-drains, where there is a water-closet attached, are periodically under the influence of flushing, by the use of the closet and the emptying of slops in the course of the day. On washing-days sudden rushes of water thrown down the sinks furnish a very powerful means of flushing and removing obstructions; and every shower of rain, where the stack-pipes are judiciously placed in reference to the house-drains, is a powerful concomitant to the efficiency of a *non-absorbent* tubular system of drainage, in which not the least quantity of water that finds its way into the drain will be uselessly expended.

It is clear to you then that the small tubular system of drainage will require a much less quantity of water than is required for the existing system of brick drains?—Yes, quite so. In practice we invariably find such to be the case; as in the tubular system the whole of the water that is sent down the drain would be brought to act upon the deposit, which would be suspended, and thus prevented from accumulating; on the contrary, in brick drains very little of the fluid finds its way to the outlet of the drain into the sewer, being absorbed by the material of which the drain is composed—generally of place (or imperfectly burnt) bricks—or percolating through the numerous open joints of the brickwork, leaving the more solid portion of the sewage to become indurated, and ultimately to choke the drain.

Mr. William Baddeley.

Mr. Baddeley.

1. You are, I believe, an engineer?—Yes, and for four years I have been Inspector to the Society for the Protection of Life from Fire.

2. Then you have attended many fires?—I do constantly, and have done so for the last 30 years. I have given a great deal of consideration to the subject of water supply at fires during the last 30 years, and have been in early attendance at all the principal fires in the metropolis during that period.

3. Between the time of alarm of fire being given, and a brigade engine being brought to bear, what time, with the present arrangement, elapses before the engine is on the spot?—At Islington, where I reside, the time might be about 40 minutes; but in the City, where the stations are closer together, the time would be, I should say, from 15 to 20 minutes; there would be 3 minutes for mustering the policemen, and the engine-station would be, say 10 minutes off; in 5 or 6 minutes the engine would be got out, and then 5 minutes would elapse before it

was on the spot. The turncock is most probably on the spot first, so that 23 minutes altogether would be a fair average time in any district. Mr. Medworth.

4. What proportion of fires do you think might be avoided by the adoption of efficient means?—The number of fires last year was 838; and if there had been the means of applying water immediately, two-thirds of them would have been stopped immediately.

5. Would you say that the means of applying water in adequate quantity within 5 minutes of the commencement of a fire would prevent the progress of two-thirds of them?—Yes, about that time.

6. In some places has not delay occurred from the turncocks being at wide intervals?—Yes, on the south side of the Thames particularly. It is generally objected by the Companies that none but their own servants shall have command of the main-cocks in order to prevent confusion, as though it is necessary to have one or two cocks open, it is necessary to close two or three others to get the supply of water at the required spot.

7. Under a high pressure system of course there would be a much stronger jet given than can be procured by an engine?—Yes, certainly.

8. And you think, with such an apparatus, that two-thirds of the fires might be stopped?—Yes, they might be stopped immediately.

9. Then, from your experience, you have no doubt that the prompt application of water would be most beneficial?—I have no doubt whatever.

10. And should there not be an inquiry also afterwards?—Yes, a subsequent inquiry is most useful.

(The witness is here shown the evidence of Mr. Lindley, as to the efficacy of the constant supply of water in putting an end to fires, and states, that he quite agrees as to the important effects of such a supply in this respect.)

11. Does not the fire brigade prove as efficient as all the rest of the assistance at fires put together?—Certainly.

12. Have you not been so much impressed with the importance of an immediate application of water that you have invented various engines to promote it?—I have. The usual sizes of the brigade jet pipes run from three-fourths to seven-eighths of an inch, and the quantity of water delivered, about 90 gallons per minute. When the fire is raging in warehouses, or other buildings of great extent, even this size, or larger jets, may be used with advantage, but in the earliest stages of a fire a very much smaller quantity applied, so as to cover an extensive surface at once, is infinitely more useful in extinguishing the fire, while the damage done by the water is kept at a minimum. The truthfulness of this principle has long been established in the minds of scientific men, but little progress has been made in its practical application. Although the engines of the London Fire Establishment have the convenience of attaching two distinct lines of hose, none of them, that I am aware of, carry smaller nose pipes for that purpose, so that where a fire requires to be met at two points, the front and rear of a building for instance, two engines are constantly employed, thus throwing in 180 gallons of water per minute, whereas even 90 gallons would have been more than enough if judiciously applied. Water applied in a form of a jet is frequently unsuited to the character of a fire, as in the case of hay and

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other stacks, large surfaces of weather boarding, and such like matters, where a large burning surface requires to be covered and extinguished, but where there is no mass of fire to be dealt with; in these cases the jet is inapplicable. In order to render a *small* quantity of water effectual in extinguishing burning surfaces of considerable extent, I invented a *spreader* to be applied to the nose-pipe, kept back out of the way of the jet by a spring, until the thumb was pressed upon a lever, which brought a fan-shaped spreader over the jet, which became broken up, so as to cover a very large space. This invention was registered, agreeably to Act of Parliament, in May 1842, and Mr. Merryweather, fire-engine manufacturer of Long-acre, London, was licensed to manufacture and sell them. These *spreaders* have been used in agricultural districts with great success.

The fire police of Liverpool, Manchester, and Sunderland, have long used them; but the London Fire Establishment, with their usual apathy towards inventions not originating with themselves, have *not adopted* this useful contrivance. In February 1849, I made a considerable improvement in the *spreader*, of which Messrs. Warner and Sons, Jewin-crescent, became the purchasers, and it was registered in their name, and as applied to garden and fire engines, is coming into very extensive employment. In carrying out my convictions of the efficacy of small supplies of water, judiciously applied for extinguishing fire, in 1847, I designed a farmer's fire-engine, well adapted in all respects to give effect to these intentions. In the beginning of 1848 I constructed a portable fire-engine adapted for domestic use, calculated for the working of one man, to be put into a pail or bucket, and furnished with a length of hose, branch pipe, and spreader, so that in all cases of fire, in a single apartment, one pail of water thus applied would suffice for the extinction of the flames. A German, some years ago, showed that a large burning surface could be effectually covered with a small quantity of water, and it has been my object to carry that idea efficiently into practice. Of the 838 fires in the metropolis, in 1849, I calculate that two-thirds might have been extinguished by the prompt application of my portable fire-engine by the inmates themselves, and that the same apparatus in *experienced* hands would have sufficed for the extinction of *three-fourths* of last year's fires. A small hand-pump of less power than mine has been used by the London Fire Establishment during the last 12 months as an auxiliary to the fire-engines rather than as a substitute for them; these hand-pumps, however, have proved very useful, and it is to be hoped their sphere of usefulness will be yet further extended. Without a *spreader*, however, they lose more than half their efficacy.

13. On the whole you concur with the evidence which has been given that a constant supply of water would diminish the number of fires?—It would diminish them, not in number but in extent, and it might tend to check the number of incendiary fires. It is difficult to imagine any provision by which the occurrence of fires will be prevented, but every improvement which renders dwellings less combustible and more fire-proof, which shortens the time of bringing remedial measures to bear upon the destructive element, or increases their efficiency, must materially reduce the extent of damage by fire. Even if unaccompanied with other amendments, the use of incombustible stairs in our buildings,

and the supply of water under pressure being constant, would be of immense benefit in checking the spread of accidental and wilful fires. Mr. Baddeley.

14. Besides the increased chance of fires being extinguished from the immediate application of water, would there not also be a benefit from the decreased damage resulting from the use of a smaller quantity of water?—The amount of damage from water is now unnecessarily large.

15. What were the proportions of the total losses at last year's fires?—The total number of losses last year amounted to 30 out of the 838 fires. In more than 200, the contents of the buildings were very seriously damaged. It sometimes happens that the damage by fire is very small, and the damage by water very large.

16. Would it not be a great advantage that the police should have keys, so as to get at once at the water?—They are the only parties who could give efficiency to a system of this sort.

17. Of course, diminishing serious fires two-thirds in number would diminish the general risk in the same proportion?—It would diminish the risk in a still greater proportion.

18. Do you not find, from your experience, that an apparatus kept for extraordinary events is seldom kept in good order, or in a state of readiness?—Such is certainly the case.

19. And, therefore, it would be of great advantage if the apparatus, which would be of service in the case of fires, were otherwise kept in constant use?—Yes, and by that means the persons who would have charge of it would become familiarized with the use of it.

(*The Witness gave in the following tables.*)

TABULAR EPITOME of METROPOLITAN FIRES, from 1833 to 1849. By W. BADDELEY, 29, Alfred-street, Islington.

YEARS.	Slightly damaged.	Seriously damaged.	Totally destroyed.	Total Number of Fires.	False Alarms.	Alarms from Chimneys on Fire.	Total Number of Calls.	Insurances: On Building & Contents.	Insurances: On Building only.	Insurances: On Contents only.	Insurances: Uninsured.
1833	292	135	31	458	59	75	592	..	..	..	..
1834	338	116	28	482	63	106	651	..	..	..	..
1835	315	125	31	471	66	106	643	..	..	..	..
1836	397	134	33	564	66	126	756	169	73	104	218
1837	357	122	22	501	89	127	717	173	47	76	205
1838	383	152	33	568	80	107	755	161	59	128	220
1839	402	165	17	584	70	101	755	169	58	115	242
1840	451	204	26	681	84	98	863	237	92	104	248
1841	438	234	24	696	67	92	855	343	149	52	152
1842	521	224	24	769	61	82	912	321	116	112	220
1843	489	231	29	749	79	83	911	276	124	107	242
1844	502	237	23	762	70	94	926	313	138	94	217
1845	431	244	32	707	81	87	875	313	107	73	214
1846	576	238	20	834	119	69	1,022	302	137	125	270
1847	536	273	27	836	88	66	990	263	125	157	291
1848	509	269	27	805	120	86	1,011	310	120	134	241
1849	582	228	28	838	76	89	1,003	368	163	72	235
Total .	6,574	2,955	365	9,894	1,150	1,307	12,351	3,718	1,508	1,453	3,215
Average	470	211	26	770	82	94	882	266	108	104	230

Mr. Baddeley.

ABSTRACT of CAUSES of FIRE in the METROPOLIS, from 1833 to 1849, inclusive. Compiled by W. Baddeley.

YEARS.	Accidents of various kinds, for the most part unavoidable.	Apparel ignited on the person.	Candles, various accidents with.	Carelessness, palpable instances of.	Children playing with fire or candles.	Drunkenness.	Fire-heat, application of to various hazardous manufacturing processes.	Fire-sparks.	Fireworks.	Fires kindled on hearths and other improper places.	Flues foul, defective, &c.	Fumigation, incautious.	Furnaces, kilns, &c., defective or overheated.	Gas.	Gunpowder.
1833	83	.	56	28	.	.	31	.	.	7	71	.	.	20	3
1834	40	.	146	.	.	2	24	.	.	.	65	3	11	25	3
1835	14	.	110	19	5	3	39	.	3	9	69	7	2	39	.
1836	13	7	157	18	6	.	34	7	.	5	72	5	9	38	1
1837	17	7	125	7	18	2	22	10	5	5	53	2	12	31	3
1838	36	5	132	17	5	4	40	12	3	15	58	1	15	42	1
1839	25	3	128	14	12	6	26	9	5	8	58	5	20	72	2
1840	26	12	169	24	21	5	29	17	1	7	89	3	15	48	.
1841	26	5	184	25	18	5	16	13	4	8	83	2	12	48	.
1842	44	9	189	19	16	11	36	23	7	9	90	2	23	52	3
1843	19	5	166	27	20	6	14	17	5	9	105	1	19	40	1
1844	11	4	205	15	23	9	21	27	3	8	84	1	17	33	.
1845	17	3	165	14	19	7	22	24	10	12	78	3	29	54	1
1846	29	3	229	15	25	9	25	32	9	7	86	4	28	53	.
1847	20	3	237	20	16	5	16	65	6	3	78	4	14	63	2
1848	19	1	237	23	19	3	22	63	1	4	56	4	16	65	.
1849	13	2	241	24	15	7	23	40	8	4	78	2	21	57	2
Total .	452	69	2,876	309	238	84	440	359	70	120	1,273	49	263	780	22
Average	27	4	169	18	14	5	26	21	4	7	75	3	16	46	1¼

YEARS.	Hearths, defective, &c.	Hot cinders put away.	Lamps.	Lime, slaking of.	Linen, drying, airing, &c.	Lucifer matches.	Ovens.	Reading, working, or smoking in bed.	Shavings, loose, ignited.	Spontaneous combustion.	Stoves, defective, overheated, &c.	Tobacco smoking.	Suspicious.	Wilful.	Unknown.	Total.
1833	.	.	.	.	.	.	6	.	.	7	18	.	.	3	125	458
1834	.	.	.	3	.	.	.	3	6	2	20	6	.	9	114	482
1835	.	.	.	4	22	.	.	.	9	5	11	4	.	6	91	471
1836	.	.	2	3	31	.	6	.	13	4	28	1	.	8	96	564
1837	.	.	3	.	48	8	3	.	8	4	36	3	7	5	57	501
1838	.	.	9	4	32	9	11	1	17	5	31	4	8	6	45	568
1839	.	.	4	2	26	17	4	2	8	13	24	11	6	7	67	584
1840	.	.	3	2	25	18	13	.	27	11	48	9	11	9	39	681
1841	.	.	5	5	27	16	13	5	35	22	54	22	7	13	23	696
1842	3	3	2	4	41	17	13	2	22	20	32	17	9	19	32	769
1843	5	3	2	2	33	14	10	3	31	23	58	14	16	21	60	749
1844	2	7	6	3	45	19	10	.	18	34	44	21	7	11	74	762
1845	.	10	11	9	30	12	8	.	25	19	51	19	9	14	32	707
1846	4	8	7	7	39	14	8	3	35	18	43	29	7	19	39	834
1847	3	9	2	5	34	9	8	1	37	15	37	18	17	17	72	836
1848	4	5	3	5	36	23	2	1	27	7	48	37	11	25	38	805
1849	3	11	17	3	40	12	2	1	21	19	43	24	10	19	76	838
Total .	24	56	76	61	509	188	117	22	339	228	626	239	125	211	1,080	11,305
Average	1½	3	5	4	30	11	7	1⅓	20	13	37	14	7	12	63	665

Lord Morpeth's Charge to the Jury.

Metropolitan Sewers.—Westminster, &c.

Charge to the Jury (delivered by Lord Morpeth, M.P.), April 6, 1848.

Gentlemen of the Jury,

You are summoned here by virtue of a provision in the Statute of the 23rd of Henry VIII., which authorizes the Court "to inquire by the oaths of the honest and lawful men of the shire or shires, place or places, where defaults or annoyances be, as well within the liberties as without (by whom the truth may the rather be known), through whose default the said hurts and damages have happened, and who hath or holdeth any lands or tenements, or common of pasture, or profit of fishing, or hath or may have any hurt, loss, or disadvantage by any manner of means in the said places, as well near tó the said dangers, lets and impediments, as inhabiting or dwelling thereabouts, by the said walls, ditches, banks, gutters, gotes, sewers, trenches and other the said impediments and annoyances."

At the time the Statute was passed, there were few or no valuations, for other purposes, available for the purposes of sewers'-rate; the works to be executed were more simple, and the properties to be charged fewer. The author of this Statute of Sewers could not have contemplated that it would ever fall to the men of the county to assess, in one single district, between fifty and sixty thousand individuals, or the owners of more than fifty thousand tenements, occupied by nearly half a million of population, having a rental of upwards of three millions sterling, comprising immense varieties of properties. This multitude of properties renders it impracticable for you, within any reasonable time, to make direct inspections and adjustments of that part of the Westminster Commission this day brought before you, called the Eastern Division of the Westminster Sewers, within which there are nearly 15,000 separate tenements, with a rental of about 800,000*l.*; and it is necessary to have recourse to some intermediate agency or assistance to guide your decisions. This assistance is afforded by the valuations of properties to the poor-rate.

From the absence of appeal, however imperfect this test may be, we must assume that the parties are satisfied with that valuation, and that it is the true one. All that remains to be done for your satisfaction, and to enable you to perform your duty, is to present to you evidence as to who are rated to the poor's rates, and at what amounts, from which you will determine who are the parties to be assessed to the sewers' rates. This evidence will be given to you, with whatsoever assistance you may require, by the officers of the Court.

Looking at the multitude and varieties of properties, you will perceive that, if you felt disposed to go through the whole and found your presentments on original valuations of them, with the little means of assistance which could be afforded to you, and giving you credit for a great extent and variety of knowledge, you would in all probability come to less satisfactory results than by taking the evidence of the poor's-rates which will be submitted to you. And here it is right that you should be informed that the rates now required will be for the payment of old debts rather than the creation of new ones. The same is the case in other districts.

Since a jury of the men of the county was last convened, the dis-

Lord Morpeth's Charge to the Jury.

trict, for part of which you are acting, though still continuing separate in form, is practically consolidated under one set of Commissioners for the whole of the metropolis, with the exception of one part of the drainage area. The most important point in which the Westminster District now before you must be interested, is that which might be elicited by the question—

What has this consolidation, carried out by the Government, done for us?

To take as an illustration the last subject under the consideration of the Court of Sewers—namely, the establishment of paid officers—

It has given you a large increase of valuable service, without any increase, probably with much diminution of expense.

For the Westminster District there was formerly one Chief Clerk Mr. Hertslet, and one Chief Surveyor, Mr. Phillips—able and efficient, public officers, who are both retained for your service, whilst they are advanced to a higher sphere of duty, and to more satisfactory because more efficient service. But the improvement of drainage-works demands scientific appliances and various abilities. We have added to the engineering force, Mr. Austin, as a Consulting Engineer, who has long studied the subject of town improvement; and Mr. Roe, who, as Surveyor to the Holborn and Finsbury Divisions, took the earliest lead in the improvement of this branch of the public works. Adopting the recommendations of the Sanitary Commissioners, we have deemed the improvement of these works so important to the public health, and the proper performance of the service so needful, as to require undivided attention. We have considered that these services could not be properly attended to as incidents to private practice. We have, therefore, resolved that all salaried officers throughout the several Commissions shall, in this department at least, give their whole time to the public service, and shall be freed from private practice. We have, moreover, abolished per-centages on works executed. We have, moreover, abolished all fees.

In the surveyor's department, we have appointed as an Assistant Surveyor, Mr. G. Donaldson, who was specially conversant with land-drainage, to attend to the subject of the drainage of the low-lying and open marshy land within the district, by which the sanitary condition of the covered district adjoining is affected. Having observed talent in the report of a Surveyor to the Paving Board of St. Andrew's Holborn, and St. George the Martyr, and evidence of special acquaintance with the subject of house-drainage, we have engaged that surveyor, Mr. Lovick, as an assistant surveyor in this service.

Mr. Stable, the highly-respectable Clerk of the Holborn and Finsbury Division, we have engaged to take special charge of the collections and disbursements of the rates. We also availed ourselves of the services of Mr. Grey, a public accountant, to systematise the accounts, and to enable us to throw light on the pecuniary branch of the administration.

By the consolidation, you have gained the additional services of one Chief Clerk, of a Consulting Engineer, and one Chief Surveyor, and two Assistant Surveyors, without any increase of expense to the Westminster District. The establishments and the payments are not yet fixed; but to the whole of the districts in the metropolis the consolida-

tion has been attended with this undoubted gain of service, with a reduced expense. The reduction in the surveying staff has already been from upwards of 6,000*l.* per annum for fragmentary and imperfect service, to 4,700*l.* for a consolidated and improved establishment. The gain to each of the other districts consolidated will be similar, and each has now available the services of the entire staff, and with a considerable reduction of expense.

Lord Morpeth's Charge to the Jury.

Secondly, you gain by the consolidation in all that efficiency of works which is dependent on systematic operations on a wide basis; or, in other words, you have had averted the worse than waste which is incurred by operations on a narrow basis, by feeble establishments acting on limited information.

When we entered upon our duties, the sewers of the district were, and unfortunately yet are, and with our best efforts are likely too long to continue to be, what your officers have described them to be—extended cesspools. We have had sewers in the same district running different ways; sewers made at great expense, which accumulate pestilential deposit (90,000 tons or 62,000 cubic yards of which we have had flushed away): all these works incurring waste of money for sewering the district ill, which would more than have sufficed not only to sewer it but to drain the houses well and abolish the pestilential cesspools over which they are built. Much of this waste has arisen from the want of a proper system of survey. The remedy for future works is to obtain a proper survey. This more perfect work, which will govern not only main drainage but house drainage, the better construction of streets, the better distribution of water, the identification of properties, better valuations, and the more equal collections of rates, increased efficiency or reduced expense of future works, you gain by consolidation.

One gain by the systematic works is, the better adaptation of sewers to the run of water which they are to discharge. That class of works has not yet been completely systematised. Until the survey which we propose to make is more advanced, we may not expect any new system of works to be completed. We have, however, in particular instances, and in cases of emergency, directed new sewers to be made. We may present as examples the new portions of Sewers brought under the consideration of the Court at the last General Court day, viz.:—

	£.	s.	d.
In Winchester-row, New Road.—An estimate for a 4-inch pipe even from each house, instead of a brick drain, as required under previous practice	171	8	4
Ditto for drain at back, instead of the new mode just mentioned	52	6	3

The second estimate was approved.

In Dean-street, Soho.—1,300 feet to 470*l.*, including junctions for house-drains, was ordered, for which the estimate in 1843 was 1,412*l.* without such junctions for house-drains.

In Bedfordbury, St. Martin's.—130 feet of sewer is to cost 33*l.*; in 1841, 190 feet at the lower end cost 278*l.* 5*s.* 5*d.*

Lord Morpeth's Charge to the Jury.

'You may be aware how much of the suburban drainage consists of open ditches at the bottom of gardens. The following is one instance of this kind where an uncovered ditch of 10 or 12 feet wide was complained of as offensive:—

Gloucester-street, Shoreditch.—Estimate for 860 feet of pipe-drain in lieu of open ditch, 215*l.*; former estimate, 600*l.* Nearly a quarter of an acre will be recovered by filling up the ditch. A space of garden-ground, 10 or 12 feet wide, will be gained to each house as a flower-bed, in the place of a stagnant ditch.

The foregoing cases may be briefly stated as follows:—

	Old Plan.			New Plan.		
	£.	*s.*	*d.*	£.	*s.*	*d.*
Winchester-row, New Road	171	0	0	52	0	0
Dean-street, Soho	1,463	0	0	470	0	0
Bedfordbury, St. Martin's	200	0	0	33	0	0
Gloucester-street, Shoreditch	600	0	0	215	0	0

We have before us two reports for the future drainage of Westminster, comprehending varied applications of the similar principle. We may present an estimate from one, not because it is determined upon yet, but because it furnishes an exemplification on a larger scale of the economies to which we hope to approach,

The comparative cost of drainage-works formerly constructed, and of those now proposed on spaces equally covered would stand thus:—

Per lineal Mile.

	Annual Cost of Flushing, Cleansing, and Repairs.	Average rate of Principal and Interest per house, reckoning 320 houses per mile.		
	£.	£.	*s.*	*d.*
Expense of works as formerly constructed, 5,000*l.*	70	1	2	$2\frac{3}{4}$
	Annual Cost of Pumping and Maintenance. £.			
Expense of the system at present proposed, 1,000*l.*	25	0	5	

The proposed works costing less than one-fourth of the former system.

In respect to the more temporary operations of cleansing, we may mention, that at the contract price for cleansing under the old system, by the offensive mode of hand-labour and cartage, the expense would have been at per load (taking the sum paid by the city of London, and taking an average of the other districts), 7*s.*, or for 62,000 cubic yards, 21,700*l.*; while the actual cost under the new system, including every expense, has been 4,650*l.*

Lord Morpeth's Charge to the Jury.

We have endeavoured, as far as our powers would permit, to turn the principle of flushing to account for the relief of the poorer districts, and by the removal of the contents of cesspools by means of the pump and hose; and this we have accomplished at less than one-third of the cost, and without any of the usual offensive and injurious effects of the operation.

In respect to the management of the rates, besides reducing the collections we have not thought it of advantage to give to one great company (the Bank of England) the undivided profits on the balances of the rate-payers' money in our hands; but, having obtained freehold security from another banking company, and they having given, with greatly increased facilties for transacting business, interest at the rate of two per cent. per annum on the current balance, we have thought it right to open an account with them; and with this saving of interest we expect to pay the salary of two additional assistant surveyors at the least.

The gains from consolidation, then, are, the increase of the force of the establishment, the increase of the efficiency of the works, and a reduction of the expense.

Our future progress, we expect, will be in the increase of efficiency. The surveyors have at present under consideration improvements in house-drainage which we expect will be accompanied by similar reductions in expense concurrent with the improvements.

Further advances to the completion and perfection of the works and the administrative service must be dependent on the completion of the drainage district, and on the consolidation of other connected works within our present district, under one and the same competent management.

Had Westminster remained under a management separate from the other districts, effluvia arising from any deposit created by defective cleansing in this district would not only have been diffused in greater quantities than it yet is amidst your habitations, but if the sewers and drains within your own districts were perfectly well cleansed, you would still, on the prevalence of certain winds, be exposed to the miasma carried from the ill-cleansed sewers in other parts of the drainage area.

Your own position may be shown by contrast; but representations having been made that increased expenses would be consequent upon the consolidation, or what is termed the centralization, of our local institutions, at this time of real pressure it is important that the truth should be known, and what has been the fact, and that the course of real improvement is one of economy and of reduction of burthens. The sewers' rates have been, and might continue to be as they would be under separate management, worse than wasted. But sickness and disease, and premature disablement, not to speak of premature death, entail heavy pecuniary burthens, and all well-devised works, and carefully-applied expenditure, must be in diminution of some of the most serious burthens, and tend to give health and strength to meet others which may be less preventible. The rates now required will be confidently applied in reduction of those burthens. But an increase of efficiency in their application depends on the completeness of the powers given for the purpose. In respect to works, an estimate has been cited

Lord Morpeth's Charge to the Jury.

to show that a complete system of main sewerage may be expected for all Westminster at a charge not exceeding 5*s.* per house per annum, or little more than 1*d.* per week, for works more complete and certain than any which now exist.

When we are speaking of expenses, we must notice one item of reduction which we have felt it our duty to enforce. The Statute under which we act makes no provision for dinners, and we have discontinued that practice. If it were discretionary with us, we should not think it good policy to hold forth the pleasures of the table as an inducement to the service. In strict law, however, we have felt it our ungracious duty to disallow payments for dinner-bills of our predecessors to the amount of 186*l.* for the last two months they were in office. We take no dinners ourselves, and I fear, gentlemen, we can offer no public hospitality to you.

"On analysing the business of District Courts meeting weekly, fortnightly, monthly, or quarterly," say the Sanitary Commissioners in their First Report, "it appears that a large proportion of it arises from the very defects of their own plans and works, which under an amended system will disappear. Those who have paid attention to the despatch of large amounts of varied business, are aware that, up to certain limits, the larger the amounts, the more complete are the means of classifying and systematizing it, the better the real despatch of it. We would cite, as an example, the consolidation, under the Metropolitan Roads Commission, of the administration of the roads formerly administered by a number of local trusts, comprehending the suburban parishes in the metropolis. Under that Commission, the roads have been improved, the tolls and the debts reduced, and the business of 100 miles of road transacted satisfactorily, with less attendance and consumption of time on the part of the honorary members of the Board than was previously required, by the defective despatch of business, by any one of the numerous separate Boards under which important improvements were found to be impracticable. It may be averred that the business of a Commission of Sewers for the whole of the metropolis may eventually be despatched better and more expeditiously than the business of one of the single Commissions."

London: Printed by W. Clowes and Sons, Stamford-street,
For Her Majesty's Stationery Office.

GENERAL BOARD OF HEALTH.

REPORT

ON THE

SUPPLY OF WATER

TO

THE METROPOLIS.

APPENDIX No. III.

REPORT AND EVIDENCE—MEDICAL, CHEMICAL, GEOLOGICAL, AND MISCELLANEOUS.

Presented to both Houses of Parliament by Command of Her Majesty.

LONDON:
PRINTED BY W. CLOWES & SONS, STAMFORD STREET.
FOR HER MAJESTY'S STATIONERY OFFICE.
1850.

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Dr. Sutherland's Report.

My Lords and Gentlemen,

In compliance with instructions received from the General Board of Health, I have made a series of inquiries in regard to the sanitary and economic advantages of soft water supplies for domestic and manufacturing purposes, in a number of towns both in Lancashire and Scotland, which were formerly supplied with hard water from rivers and pump-wells, but have recently been furnished with soft water from gathering-grounds and other sources. Dr. Sutherland.

The objects of my inquiry were not of a chemical nature, but were rather directed to ascertain from the people themselves, and from medical men, manufacturers, brewers, and other well-informed parties, what perceptible advantages had followed from the use of waters which chemistry had previously pointed out as likely to be more wholesome and cheaper than those previously in use. While thus engaged, facts of a very important nature in regard to the whole question of water-supply were brought under my notice, and I was directed by the General Board of Health to extend the inquiry, so as to comprehend these particulars also, and I now beg respectfully to lay before you the results of the whole investigation.

Economic Advantages of Soft Water.—I made inquiries on this subject in the towns I visited, both in England and Scotland; and I found that all parties, without exception, were unanimously of opinion, that very great economy had been effected by the introduction of soft water: evidence to this effect was given by engineers, manufacturers, bleachers, and brewers, while similar testimony was offered by persons using water only for domestic purposes. I select the following examples because the introduction of the soft water having lately taken place, it was more easy for the people to institute a comparison.

The experience of the town of Stockport is valuable, as affording an example of the use of two kinds of water, one of hardness of $16\frac{1}{2}°$, or about that of the Thames water, and the other of $3\frac{1}{2}°$, or about the amount of hardness of supplies proposed to be collected from gathering-grounds. Both are supplied by the water-works Company, the harder water derived from springs in the new red sandstone, being known as the lower level water, and the softer supply as the *higher level water*. The following are notes of evidence obtained from Mr. John Lawton, waterman to the Company:—

"All the consumers like the higher level water better than the lower level water, because the higher level water is the softest." The consumers "want it for tea, and for washing, it makes much better tea, it uses less tea, it uses decidedly less soap. It is cheaper for washing, and there is less labour attending it. It is preferred by the brewers, because it brews better ale. The soft water does not corrode boilers. At large tea parties the soft water is used by preference, because it makes tea cheaper and better."

Dr. Sutherland.

Being asked, "What is the reason people pay for your water, when they can get a supply from their own wells without paying for it?" He replies, "For the reasons I have already given. These give the universal opinions of the people, so much so that the Company has determined to supply all the districts with soft water on account of its being preferred."

John Manchester, a bleacher in Stockport, gives evidence as to the superior economic value of the soft water supply. He says, "Where we should use 50 lb. of alkali with hard water, we use 45 lb. with soft. Hard water takes more alkali and soap, to produce the same colour, than soft water does. The saving of soap is still more in proportion."

In reply to the question, "What is your experience with regard to the use of hard and soft water for calico printing?" he says, "Soft water takes decidedly less drugs to produce the same colours."

Another witness, Mrs. Unsworth, of the Mersey Inn, Stockport, stated that there was an old well in the yard of the house, from which water was drawn by a steam-engine for household use, but after having gone to this expense, it was thought better to take the Company's water, on account of its softness. She states that it brews better ale than the well-water, and also makes better tea, and uses less soap in washing, so that it was found cheaper to use the soft water than the well-water, although the former had to be paid for.

The town of Blackburn has a water supply of from 3° to 4° of hardness, which has been extensively introduced into factories and dwelling-houses. I made personal inquiries of a number of people, as to their experience of the new supply in comparison with the water formerly in use. I found the testimony unanimous as to the superior advantages of the soft water for all culinary and domestic purposes. It was stated that it made better tea, and that it saved labour and soap in washing. A respectable chemist and druggist said that he could use no other water for making infusions, as all others were hard and extracted badly.

The following notes of evidence will show the superior value of the soft water supply in the local manufactures:—

Henry Smithies—"Is an engineer at Blackburn. Is acquainted with the comparative use of hard and soft water for boiler purposes; is acquainted with the use of the present town water for boiler purposes. The town water is very superior; it does not produce scale, which the former hard water did. The hard water crusted the boilers so thick, that the crust had to be taken out with a pick-axe: the bottoms of boilers got corroded, and the rivets got eaten off. There is no question as to the superior cheapness of soft water, because the boilers last very much longer and require fewer repairs. The saving of repairs in a boiler in use in our own works made more than the difference of the water-rent paid for the soft water."

Another witness, Henry Heywood, manager of Throstle-nest Mills, states, that he can confirm Mr. Smithies' testimony in every particular. "We had," he says, "to use the brook water for about a month in the summer of last year, and our boilers got a quantity of scale on in that time; but after we got the town's water, the scale all disappeared, and the boilers are now perfectly clear from it."

In regard to the superior advantages derived from the soft supply for brewing, William Astley, clerk to Mr. Dutton's brewery, states, "that there is good clear water to be obtained from wells on the premises, but

Dr. Sutherland.

that the soft town water is preferred and used, because it makes better ale, and extracts the malt better."

The water supply of Warrington, although having a hardness of $8\frac{3}{4}°$, is still much softer than the water formerly obtained from the wells of the town. Mr. Riley, secretary to the Company, states that it has been introduced into all the large breweries, and also into many public-houses brewing their own beer, although the parties have wells on their premises. The saving in tea from the use of this water has been estimated at one-third of the quantity used. It also requires much less soap in washing, and is found to be superior to the well-water for all culinary purposes.

Having been informed that very satisfactory results had been obtained in using soft water for locomotive engines, I applied to Mr. Hawkshaw, engineer to the East Lancashire Railway, for information as to his own experience on the subject.

From its local position this railway affords good means of comparison, as there is one quality of water supplied at Bolton and another at Manchester, the former being a very soft water and the latter a hard one. The following is the opinion of Mr. Hawkshaw:—" I beg to state that the water supplied by the Bolton Water Works Company has always been considered by me much superior to that obtained from the Manchester Water Works Company. Its great purity and softness tend much more to the preservation of the tubes and the interior of the boilers. From the water obtained at Bolton, there is scarcely any deposit, while from that obtained at Manchester the earthy deposit is sometimes considerable."

The town of Bolton has been supplied with a water of about 2° of hardness for a considerable number of years, but another water with a hardness of about 5° is still in use in some parts of the town. A direct experiment was made last year at the Bolton Workhouse to test the economic values of these waters, the very satisfactory results of which have been communicated to the General Board of Health.

At first sight it might appear doubtful whether so small a difference in hardness as 3° could have led to such results, but the facts have been confirmed by experience in other cases, and even the poor themselves know very well the difference of cost in washing with different qualities of water.

As an illustration of this I may state, that while examining into the subject at Paisley, I asked a woman who was washing whether she preferred town water or rain water for the purpose: she immediately gave a decided preference to rain water, and on being asked the reason, said that it used less soap and soda and required less labour than the other. Now the Paisley water happens to be one of the softest in the kingdom, having a hardness of only about 2°.

It appears to be something like a positive injustice to give the poor no alternative between want of cleanliness and the labour and expense involved in washing with water of from 12° to 16° of hardness, where a softer supply might be attainable, and yet this state of things exists in not a few of our largest cities and towns.

I need hardly multiply opinions or examples; suffice it to say that those economic advantages which chemistry had pointed out as likely to arise from the introduction of soft water supplies, have been amply realized in practice.

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Advantages to Health of Soft Water.—The first consideration in estimating the effects of water on the health of a town population, is obviously connected with the source and quality of the water.

In all the places I have visited, with one exception, the water has been obtained from gathering-grounds, collected into reservoirs, and thence distributed. Three of these collecting-grounds I have myself visited,—those of Gorbals, Paisley, and Stirling. The grounds of the Gorbals Company are situated upon an elevated, undulating tract of country between seven and eight miles south of Glasgow. They are chiefly under pasture, a portion only being under cultivation, and tile-drained. The soil was said to be from 18 inches to 2 or more feet in thickness, and to rest on till, which in its turn rests on green-stone. Sections showed the water proceeding from the upper surface of the till, after having drained through the soil. There is a little peat on these grounds, but not much; and it was stated to me that it had been proposed at one point to cut off an area of peat by a separate drainage, to convey the water from it in another direction.

The gathering-grounds of Paisley are situated between two and three miles south of the town, upon the north slope of a ridge of considerable elevation, but not so high as those of the Gorbals. The slope of the grounds is steeper, so that a large quantity of water is collected notwithstanding the porous nature of some portions of the subsoil. They are all under pasture, and have a little brushwood here and there upon the surface. The water is collected by a catch-drain, down which it flows rapidly to the reservoirs.

The Stirling gathering-grounds are situated on a lofty chain of hills to the south-west of the town at a distance of about three miles. The rock is green stone covered with a thin layer of soil, and the descent very rapid. A catch drain 1,000 yards in length collects the water from one district to the lower reservoir, and the upper reservoir is supplied by another district. The grounds are all under pasture, but there is a good deal of peat in the hollows.

The sensible qualities of the various surface waters are the following:—All are remarkably soft, and to a person accustomed to the hard water supply of London the sensation in washing is, that it can be done as well without soap in these waters, as with soap in the London water. The Stirling water was stated to have only 1° of hardness, that of Paisley about 2°, and that of Gorbals about 3½°. Notwithstanding the occurrence of peat on the gathering-grounds of Stirling, there is no evidence of its presence in the water. It is not filtered, and yet perfectly pellucid, except that on very close examination a few white floculi can be detected. The water of Paisley stands next in order of clearness. It is filtered before distribution, but contains a small quantity of suspended matter which renders it not absolutely transparent. There is nothing offensive, or which apparently could not be entirely removed by a more perfect process of filtration.

The Gorbals water is a little less translucent than that of Paisley, obviously from a similar cause and susceptible of a similar remedy.

The waters of Bolton and Bury are brown in comparison with those already described, particularly the latter, which is sent into the town unfiltered, notwithstanding the complaints made to the Water Company on the subject.

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It is commonly believed that the soft surface waters obtained from collecting grounds are less agreeable to drink than the hard waters raised from wells. The latter are perhaps cooler and clearer, from the depth at which they are procured, and the perfect process of filtration they naturally undergo. Both of these conditions, no doubt, influence the sensible properties of well water; but they are equally attainable in the waters of collecting grounds if due care be taken. The saline constituents of hard well waters are supposed by some people to make them peculiarly palatable; but, in the first place, these ingredients vary remarkably in different waters both in character and amount, and, in the next, the taste turns out to be an acquired one; for persons who have been accustomed to drink pure water are by no means satisfied at being obliged to use a harder supply afterwards.

In a communication received from Dr. Paton of Paisley the following passage occurs:—

"I was lately on a visit to my native place, Largs, in Ayrshire, and when there took a drink of water from a well that has always been esteemed very pure; but comparing it to the water of Paisley, I thought from taste that it was the opposite, being strongly impregnated with carbonate of lime. Upon testing it, the quantity was not great, the feeling had only arisen from the extra sensibility of my taste, being accustomed to water without any impregnation,—so that pure water is always pleasanter than hard water, even though there was no danger in the use of the latter."

Similar testimony has been given by a number of other persons; and from my own experience I have no hesitation in stating, that these surface waters are as agreeable to drink as any river or well water with which I am acquainted, and more so than many of them.

The comparative effects of hard and soft water on the health of town populations are beginning again to attract attention in this country. These were perfectly well known in ancient times, and have continued to be recognized on the Continent. Every medical writer of eminence, from the days of Hippocrates downwards, has dwelt upon the sanitary distinctions of the two kinds of water; and whatever be the language employed, whether that of ordinary observation or of chemical nomenclature, these writers have, I believe, with but two exceptions, given their suffrages either directly in favour of soft water or of water derived from such sources as would necessitate its being soft. They have nearly all condemned the use of hard waters, especially those containing lime in combination with sulphuric acid, such as the waters of our new red sandstone, as being directly injurious to health if constantly used, and tending to produce derangements of the digestive functions, glandular obstructions, and urinary diseases. The only authoritative names on the other side, with which I am acquainted, are those of Dr. Cullen and Dr. Darwin, the latter of whom, considers the use of hard waters to be necessary, on certain physiological grounds, which have long since been proved to be untenable. I am quite aware that to assert the unhealthy nature of hard waters, may excite surprise, but I feel confident, both on the ground of experience in my own person and observation in those of others, that such is the case. This matter was discussed in a paper which I had the honour of laying before the Board some time ago. It is true, all persons do not suffer to the same extent, and that the effects must be looked for in susceptible constitutions, but where attention is once directed to the subject, the facts can hardly be overlooked afterwards. Some of our

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best medical authorities have even gone the length of recommending distilled water as a constant beverage, and the entire abandonment of the use of hard water.

In those towns where a soft water supply has been lately introduced, I found a decided conviction prevailing among the medical profession as to the sanitary advantages of such waters, merely on the ground of their softness. The evidence goes to prove that dyspeptic complaints diminish, that epidemics are less severe and less fatal, and that stone and other calculous diseases are prevented. I beg to subjoin the following statements on these points.

Dr. Leech, who is a medical practitioner in Glasgow, in the district supplied by the Gorbals Gravitation Water-works, says—

"My attention has been called to the bearing of the question of pure soft water supply on the public health. The Gorbals water is very soft and pure. The new supply has been introduced about two years; but in consequence of the bad water supply which existed before the new water was introduced, my attention as well as that of my medical brethren was directed to the question for a long time previously. The comparative value of the new soft supply over the old hard supply has been matter of discussion at the Glasgow Southern Medical Society, of which I was president two years. It was the unanimous opinion of the medical profession, that great benefits of a sanitary kind had followed in the substitution of the soft water on the principle of constant supply. It has been observed, that since this change, urinary diseases have become less frequent, especially those attended by the deposition of gravel. So far as experience has gone, my own opinion is, that dyspeptic complaints have become diminished in number. With the same reservation as to time, it is the opinion of the medical profession that fever has numerically diminished, and that the cases that occur are more amenable to treatment by the use of the soft water supply than they were with the former supply.

"During the late cholera there was a remarkable circumstance which deserves notice as compared with the epidemic of 1832. Since the former period, the population of Glasgow south of the Clyde has nearly doubled, and with this exception, and the introduction of the soft water supply, the circumstances might be considered as the same at both periods. In one district, the parish of Gorbals, the attack in 1832 was fearful, while Glasgow, north of the Clyde, also suffered severely. During the late epidemic, Gorbals parish furnished comparatively a small number of cases, while the epidemic in other parts of Glasgow was very severe. The unanimous opinion of the Medical Society was, that this comparative immunity was to be attributed to the soft water supply."

Dr. Cunninghame, who also practises in the Gorbals district, is of the same opinion as to the sanitary advantages which have resulted from the substitution of soft for hard water in this part of the city.

I received similar testimony from Mr. Wolstenholme and Mr. Robinson, surgeons practising in Bolton, where there has been for some years a soft water supply. This has been already laid before the General Board of Health.

Although the town of Stirling has only had soft water for about a year, sanitary results have already shown themselves, and for this fact I have the authority of Dr. Forrest, of that town.

In regard to the sanitary advantages of the soft water supply at Paisley, Dr. Paton, makes the following remarks. After stating that Paisley was originally supplied with well-water, containing many mineral substances, particularly carbonate of lime and iron, for which the inhabitants substituted river water, he goes on to say:—

"In the year 1838 the water was introduced into the town by gravitation. It is a very pure quality, containing little, if any, mineral impregnation, being mostly rain-water collected over hills of whinstone, or clay porphyry. The pipes being always kept full, there is very little decomposition within them, and a

constant supply. Most of the inhabitants, I understand, nearly 90 per cent., are in the habit of using it. * * * I was not in town previous to the filtered river-water being used, but in the first ten years of my practice here, from 1827 to 1838, cases of calculous disorders were very numerous; the last ten years I have seen few or none, unless a few old cases previously affected, or in parts not accessible to the water of the Company, and a few from some of the chalk counties of England. With regard to the time previous to the introduction of the filtered river-water, which must have been about 1804 or 1805, I can communicate nothing of my own knowledge, but from frequent conversations with my partner, the late Dr. White, of this place, who had been upwards of 50 years in practice when I joined him, I was given to understand that the cases of stone were very numerous. The same thing was often mentioned by other old practitioners. They also mentioned the rapid diminution of them after the river-water came to be used in part, and now there is not a single case of calculous disease except those previously mentioned." Dr. Sutherland.

In another communication, Dr. Paton mentions several cases of renal calculi which had come under his care from distant towns. He states that these cases had had no return of the complaint for the last six months, except a slight attack in one which did not confine the patient to bed. This circumstance Dr. Paton attributes to the use of the soft water. He also says:—

"I may mention that since the 1st July 1846, I have attended 4,262 paupers for the Abbey parish, and among that number there has only been one case of calculous disorder. The boy was from Ireland, and had suffered long before coming to this country. I have had conversation with several of the surgeons here, and they all concur in the opinions expressed in my former letter to the General Board of Health, that since the introduction of the soft water by gravitation, there are almost no cases of calculous disorders, either renal or vesical."

In illustration of the benefits of soft water in diminishing epidemics, Dr. Paton states from a knowledge of the sources of the water supply in affected districts in the west of Scotland, that—

"Cholera appears, during this last and former attack, to have been more severe in those places where the water is obtained from calcareous wells, or where it is impregnated with other mineral matters, than in those places where it issued from wells over trap, or where it flows over a rocky soil of that nature. * * * I may mention that in Charleston, a district of Paisley, standing higher and possessing purer air than most of the town, and containing about 4,500 inhabitants, mostly supplied with water from wells and not from the Company, cholera made its most severe attack, hardly missing a family, except a few who were supplied with pure water. * * * When cholera prevailed, I attended many cases of diarrhœa, particularly in parts of the town supplied with wells."

A similar observation was made and published by the Local Board of Health in Paisley, in regard to developed cholera. In the same report they showed that *cœteris paribus* those parts of the town in which the gravitation water was used, were much less affected with fever than the districts supplied by wells. In regard to this report, Dr. Paton says:—

"You will perceive that where pure water has been supplied, there have been only 346 cases of fever during twelve months, and where it has not, the numbers have been 502. This difference is not so marked, but when it is considered that the larger number comes from one-tenth of the inhabitants, and the smaller from the remainder, it is then fully seen what is the value of the pure water. * * * My observations on the water of other places, as compared with this, lead me to the conclusion that no expense ought to be spared to supply towns with pure water, and that without any mineral impregnation. This, however, can only be accomplished by collecting the water from high grounds formed of trap or primitive rocks, and not from soils impregnated with lime, &c. For such a place as London, though the water was brought from Wales, the ultimate advantages would more than counterbalance all the trouble and expense, but some place perhaps could be found nearer, and of sufficient height to give a constant supply."

Such is the experience which has been obtained in towns supplied

Dr. Sutherland. with soft water, and although the surface over which the observations have been made has not, from the nature of the case, been so extensive as might have been desired, they nevertheless, so far as they go, unquestionably confirm the experience of all preceding ages and countries. I cannot therefore but express my conviction that in all towns where it may be found necessary to obtain a new source of supply, this evidence as to the peculiar advantages of soft water in regard to health should apart from the well known economic value of such water, exercise great influence in determining the selection.

Public opinion, founded on experience, is rapidly progressing towards sound views on this important subject. All the old forms of water-supply are gradually being superseded; the use of wells has given way before the introduction of supplies from rivers, and even where considerable expense has been incurred in erecting suitable works for pumping river water to a proper height, it has been discovered that there are purer, better, and cheaper sources than rivers. I have been informed that the City of Glasgow Water Company would willingly introduce a supply of pure soft water on the gravitation principle, if they had adequate securities for receiving a return for their capital, which, however the present state of the law renders very doubtful. Surface supplies are universally preferred in Lancashire to those obtainable from rivers or wells. The inhabitants of Dumfries were divided in opinion, as to whether a supply should be obtained from the river close to their doors, or from a distant lake which yields pure soft water; but after a full consideration, a decision has been come to in favour of the latter source. All the more recent water supplies in Scotland are derived from lakes or gathering grounds, and to all appearance every town in that part of the country will in a few years have similar advantages conferred on it.*

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* After having visited the collecting grounds from which are derived the water supplies for part of Glasgow, Paisley, and Stirling, I was directed by the General Board of Health to inspect that portion of the proposed gathering-grounds for the metropolis, situated in the neighbourhood of Farnham, and from a few acres of which that town at present receives its supply of water, with the view of comparing the apparent capabilities of the different sources of yielding waters of good and wholesome character. I have already stated, that the collecting-grounds for the Scotch towns are in elevated situations, and consist of insoluble and impervious mountain masses, from the surface of which the rainfall is drawn off as rapidly as possible by suitable catch-drains. The hills in the neighbourhood of Farnham, although rising to a considerable altitude in some parts, are formed of silicious sand and gravel, covered with short herbage and, in some part, with a thin layer of peat. The surface bears unequivocal evidence, that a considerable quantity of water flows over it directly to the lower levels; but the structure of the ground, and the occurrence of springs of pure water from the hill sides, show that a process of filtration through the sand and gravel takes place at the same time. The supply for Farnham was stated to be derived by tile-draining a few acres of ground. It is received into a shallow circular well, about three feet below the surface, from whence it flows into the main. At another part of the hill a stream of water was flowing after having percolated through a considerable thickness of gravel.

Present Supply and Consumption under the Constant System.— One special part of the inquiry connected with the sanitary advantages of increased water supply, was directed to ascertaining the precise quantity of water consumed by different classes of the community. It had been stated to the General Board of Health that the actual quantity drawn from the reservoirs for this purpose amounted to from 13 to 30 gallons and upwards per head per diem, for the whole population, in those towns where a constant supply had been provided. No one at all conversant with the habits of the working classes, or with the miserable deficiency of domestic conveniences within their dwellings, could for a moment entertain the idea that any such quantities were used by them, although there could be no reasonable doubt that the measurements of the water drawn from the reservoirs were accurately given. Dr. Sutherland.

I have pursued this inquiry in a number of towns, but it appears

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Both these waters have been found to be remarkably soft and pure, and in this respect in every way adapted for use. So far as their physical properties are concerned, they may be safely pronounced to be superior to those of any of the waters I examined either in Scotland or Lancashire. They are perfectly transparent, and at the time I examined them contained no floculi or colouring matter. They were cold and well ærated, arising no doubt from the perfect process of filtration they undergo, and from the fact of their retaining the temperature of the gravel bed through which they pass. At one point, the water, after flowing from the hill, rested on a quantity of peat in a hollow, and became coloured, but the same water, after having flowed over a bed of pebbles for a short distance, had lost the colour entirely, and became transparent.

The collecting of water from such grounds as those which supply Farnham involves the application of a principle of extreme importance in a sanitary point of view, namely, the natural filtration of water, and the conveying it away for use as rapidly as possible after it reaches the surface. In grounds where a considerable delay takes place between the time of rainfall and the time of delivery of the water, if there be much peat on the surface, the water becomes discoloured and requires a careful process of subsidence and filtration to remove the colour; but the experiment now going on near Farnham has demonstrated this important fact, that the atmospheric water, after having passed through a natural filter composed of insoluble materials, may be collected in abundance by a simple process of tile-draining a few feet below the surface, and delivered in a state of as great purity and softness, and at the same time with more transparency and coolness than it has been yet obtained from the surface of any collecting-ground with which I am acquainted. There were some particular portions of the ground which appeared to be faulty, but these could no doubt be avoided in selecting the surface from which the water might be obtained.

I have not seen the grounds from which Aberdeen is supplied; but from accounts I have received of them, and also of the quality of the water, I see no reason to doubt that such grounds as those which supply Farnham would yield a water as suitable for domestic purposes; and that were the metropolis to receive the benefit of such water it would have a supply, to say the least of it, as good as, if not better than that of any city of ancient or modern times

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that no estimate of the actual consumption has hitherto been made, although information of this kind must be obviously of primary importance to water Companies, engineers, and the public at large. The investigation presented considerable difficulties, especially in those instances in which the supply is obtained within the houses, and this arises from the circumstance that there is no process of measurement in using the water, the practice being to fill any convenient vessel, whatever its shape or size may be, to wash hands, dishes, and sometimes clothes, in the sink, while the pipe is allowed to run, so that no estimate of the quantity can be obtained. Similar obstacles exist in the better class of houses, which are supplied with baths and water-closets; but nevertheless an approximate estimate may be arrived at in these cases, while amongst a class which constitutes more than half of the whole population in these towns, tolerably correct measurements may be obtained. I allude to those families who derive their water supply from stand-pipes.

While engaged on the subject of water supply in the Scotch towns, I obtained the assistance of parties fully conversant with the dwellings of various grades of the working classes, and such a number of examples were taken as in the opinion of those parties afforded fair average specimens from which to draw conclusions. It is a practice with the working classes in Glasgow, Paisley, and Stirling, to carry the water from the stand-pipes into their houses in vessels of a uniform size, some of them holding 1½ gallons, and others 2 gallons. This was ascertained by direct measurement. By conversing with the people and recalling to their minds the various purposes for which they required water, there was no difficulty in learning the number of times they sent their vessels each day to be filled. It was found that the washing of clothes was performed in some instances once a-week, but in the majority once a-fortnight, and the people readily stated the quantity of water required for that special purpose. By dividing this quantity by the number of days, and adding the daily proportion to the quantity required for other purposes, the following estimates of the daily supply of each house were obtained. The people stated that the quantities given comprised all the water used for every purpose:—

Daily Household Consumption of Water from Stand-pipes in Glasgow, north of the Clyde

Houses.	Inmates.	Gallons of Water used per House per Diem.	Houses.	Inmates.	Gallons of Water used per House per Diem.
1	4	4	13	12	7
2	5	4	14	3	2
3	7	5½	15	7	6
4	2	4½	16	4	3
5	3	4	17	3	1½
6	2	3	18	5	4½
7	3	2½	19	6	3
8	7	6	20	5	2
9	4	4	21	2	2½
10	3	2¼	22	7	5
11	3	4	23	8	7½
12	3	2	24	6	3¾

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The total results of this table stand as follows:—

Number of Houses.	Number of Inmates.	Gallons of Water used per Diem.	Gallons of Water per Head per Diem.
24	114	93½	0·82

The portion of Glasgow from which these examples have been selected has a constant and unlimited supply of water from the river Clyde by pumping, and I now proceed to give the results of a similar inquiry in that part of Glasgow south of the Clyde, which is supplied with water on the gravitation system by the Gorbals Water Works Company.

Daily Household Consumption of Water from Stand-pipes in Glasgow, south of the Clyde.

Houses.	Inmates.	Gallons of Water per House per Diem.	Houses.	Inmates.	Gallons of Water per House per Diem.
1	3	4	11	7	4½
2	6	4½	12	3	4½
3	7	6	13	3	2
4	6	6	14	5	4½
5	3	4½	15	4	6
6	5	6	16	4	12
7	5	6	17	4	5
8	5	8	18	10	6
9	3	6	19	4	8
10	3	3	20	7	4½

This table gives the following results:—

Houses.	Inmates.	Gallons per Day.	Gallons per Head per Day.
20	97	111	1·14

The table which follows exhibits the household consumption from stand-pipes, under the system of constant supply in the town of Paisley.

Houses.	Inmates.	Gallons of Water per House per Diem.	Houses.	Inmates.	Gallons of Water per House per Diem.
1	3	6½	7	4	4½
2	4	6½	8	2	2
3	4	7	9	8	11
4	6	7½	10	4	3
5	4	8½	11	3	4
6	4	9	12	8	6½

The following are the total proportions:—houses, 12; inmates, 54; gallons of water used per diem, 76; total consumption per head per diem, 1·4 gallons.

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At Stirling I instituted a similar inquiry, and the result was that the quantity of water taken from stand-pipes in that town, for domestic purposes, did not exceed two gallons per head per diem.

In order to be able to form an estimate of the entire quantity of water required for the daily consumption of that class of the population supplied by stand-pipes, it was necessary to ascertain approximately the number who derived their supplies in this way. For the following estimates I am indebted to Mr. Mackain and Mr. Hodges, the managers of the water-works in Glasgow, to Mr. Holms of Paisley, and to Mr. Robertson of Stirling.

—	Population supplied by Stand-pipes.	Population supplied within their Dwellings.
Glasgow, north of the Clyde . .	160,000	165,000
,, south ,, . .	14,500	55,500
Paisley	23,690	6,000
Stirling	7,125	3,180

The estimates are formed on the assumption of a population of five to a family, which is considered a fair average; and the statement in the preceding tables, I believe to be a correct representation of the actual quantity used. I am aware that this is very much lower than is generally believed, especially when contrasted with the quantity sent into the mains per head of the population, and I was myself by no means prepared for the results which the investigation brought out. It had been so constantly affirmed that the daily supply represented the daily consumption, that I had almost arrived at the conviction, that the more moderate estimates of what could be used for domestic purposes were very much below the truth, although at the same time on considering the habits of a large proportion of the working population, I could not but feel that they did not afford very strong indications of a liberal use of this prime element of health and cleanliness.

I have heard the great discrepancy accounted for by assuming a wasteful use of the water at the stand-pipes, by washing under them; but all I can say is, that in the course of my inquiries I never met with a single such instance, and the people constantly asserted that their statements as to the total consumption were correct. However, with such an abundant waste, it is possible to be a little liberal, and I shall therefore assume the consumption at two gallons per head per day, and this amount would indicate a supply of 320,000 gallons, as being sufficient under the present system of distribution for 160,000 people in Glasgow, north of the Clyde, or nearly one-half of the entire population, provided the quantity could be delivered without waste. Some idea, however, of the extent of the latter may be formed, when it is stated that the quantity pumped into the mains for this proportion of the population, is no less than four millions of gallons a-day.

The amount required for the domestic consumption of 23,690 persons in Paisley, or about three-fourths of the consumers, would be in round numbers 48,000 gallons; while the actual quantity sent into the mains is above 450,000 gallons. Similar discrepancies will be found to exist

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elsewhere, and it must be borne in mind that these occur in populations having a constant and unlimited supply of water always at their command, the only condition being that the amount required has to be carried from the stand-pipe into their houses, and that the water used be carried out, since there are no sinks or domestic convenience within this class of dwellings.

In the various districts visited, I found very clean houses even amongst the poorest members of society, but these I am sorry to say were only exceptional cases. Setting them aside, I think it may safely be stated that the proportion of water used, affords a tolerable estimate of the state of domestic cleanliness among the poor. The smaller the quantity of water said to be used, the more filthy was the dwelling; and I feel satisfied that in the vast majority of cases, the meagre supply taken from stand-pipes is rather intended for the absolute wants of nature than for anything beyond them, the labour of carriage being an insurmountable obstacle to the liberal use of water for household purposes.

There is a considerable, and I rejoice to say, an increasing class of working men's houses within which water-pipes and sinks have been introduced; and in Glasgow several dwellings of from 6*l.* to 8*l.* rent have been recently fitted up with water-closets and shower-baths. In these, and also in the middle and upper class houses, a larger quantity of water in proportion to the inmates is doubtless used. Were there no waste from the supply-pipes, the actual quantity which the inhabitants of these houses would have at their disposal, after all the people supplied by stand-pipes had received their two gallons each, would be somewhere about 47 gallons per head per diem. A moment's consideration will show that no such quantity can be used, even taking into consideration the shower and plunge-baths with which many of the houses are provided. No extra charge is made for baths, and therefore the precise number cannot be ascertained from the water company's books; but if we assume that every house in Glasgow, north of the Clyde, of from 20*l.* to 30*l.* rent is supplied with a shower-bath, there would be 3,722 of these conveniences; and if it be also assumed that every house of 30*l.* and upwards, is furnished with a plunge-bath, water would have to be accounted for as supplying 3,329 of these. I have no doubt that these figures indicate a larger number than are in daily use; while if it be even granted that they are all used, the water required would by no means correspond with the quantity which disappears from the mains.

Notwithstanding the difficulty of obtaining accurate measurements I have been able, through the kindness of parties taking an interest in the inquiry, to procure the following information in regard to a few middle class houses in Glasgow. In one such house, with 9 inmates, the consumption was about 5 gallons per head per diem. In another, with three inmates, it was under 7 gallons per head. In a third, with 6 inmates, it was about the same quantity; and, in a fourth, inhabited by a respectable working man, it was 4 gallons per head, which includes in all the cases that used for the washing of clothes, it being the usual custom in Glasgow to perform this operation at home.

The following measurements have been sent me by Mr. Robertson of Stirling:—

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Houses.	Inmates.	Gallons per House per Day.	Gallons per Head per Day.
1	7	21	3
2	5	20	4
3	5	24	$4\frac{4}{5}$
4	5	56	$11\frac{1}{5}$
5	12	50	$4\frac{2}{12}$
6	5	43	$8\frac{3}{5}$
7	6	100	$16\frac{2}{3}$
Totals	45	314	7

The average given of 7 gallons per head is too great, as it was washing-day in houses 4 and 7, which accounts for the quantities being doubled, but as this happens generally once a fortnight the additional amount must be deducted in these two cases, and a like proportion added in the others, which would give an average consumption in the better class of houses, including washing and water-closets, of little more than $5\frac{1}{2}$ gallons per head per day.

Mr. Robertson gives an instance of four families living in the same block, and having water-closets, and supplied by one large cistern. The quantity drawn in this case was 182 gallons for 17 inmates, being at the rate of about $10\frac{3}{4}$ gallons each. In this instance also it was washing-day in two of the families. In another case 7 families consisting of 31 persons, each house being also supplied with a water-closet, consumed 284 gallons a day, or about 9 gallons each.

I have made several attempts to procure measurements of the quantity of water actually used under the constant supply at Bolton and Bury, but hitherto without success. The quantity reported to be sent into the mains at Bolton is about 15 gallons per head for each consumer, and at Bury about 16 gallons per head. As there are no standpipes, or other means of comparison, an approximation to the actual consumption cannot be obtained, but sufficient has been stated in regard to other places to show that the quantity discharged into the mains is no criterion of that which is really drawn within the houses.*

The discussions on the water question in Liverpool have led to important measurements there. I have the authority of Mr. Newlands, the borough engineer, for stating that the result of a direct experiment as to the consumption of water for all purposes, made in a first class house, including washing, baths, and water-closets, was 7 gallons per

* Since the above has been in type, I have received the following information on the subject from Mr. Harper, Bury:—"I have had Parkinson's (of Bury), patent water meter at work, in a house of 14*l.* a-year rental. Family, seven persons. The result of one week's test is exactly 287 gallons, or 41 gallons per diem. It includes a washing-day." This accurate measurement gives $5\frac{6}{7}$ gallons per head per diem, and approximates closely to the measurements in other towns. In a cottage of 3*s.* 2*d.* a-week rent the same meter gave a consumption of 6·8 gallons per head per day, in a family of seven persons. And in another family of seven persons inhabiting a house of 60*l.* a-year rental, it showed a consumption of 6·88 gallons per head per diem. Both of these examples includes a washing-day; but the last one does not give the quantity used for a water closet which happens to be supplied with rain water.

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head per diem. A like measurement was made of the supply to one of the Liverpool hospitals, and it was found to be 10 gallons per head per day; but it is only fair to state that the consumption in hospital is higher than for domestic use, on account of the large comparative quantity required for baths, and the still larger amount consumed for the continuous washing required amongst sick persons.

The Liverpool workhouse contains about 2,000 inmates, and is supplied with water-closets, baths, &c. The consumption in this house was found to be somewhat under 3 gallons per head per day.

If any reasonable allowance be made for domestic consumption, it is obvious that a prodigious waste of water must occur in some form or other. Mr. Mackain stated that the quantity pumped into the mains solely for domestic use was between 10,000,000 and 11,000,000 of gallons a-day in Glasgow north of the Clyde, which, after a large deduction for waste, would still leave 25 gallons per head of the population for actual consumption.

From the Gorbals water-works the estimated average supply is about 32 gallons per head. In Paisley it is about 20 gallons, and in Stirling 13 gallons. These are the quantities actually flowing into the mains, exclusive of the supply for public works, and all similar purposes; and yet notwithstanding the great differences in quantity, the people asserted in every case that they had as much water as they could use; in fact, the largest amount per head taken from stand-pipes was in the town of Stirling, where the absolute quantity flowing from the reservoirs is very much less than in any other instance, and it thus becomes an object of paramount importance to inquire into the causes of these discrepancies.

The very first circumstance in the inquiry which attracted my attention was the enormous and continuous waste not only from the stand-pipes, but also from water taps on stair heads, and within private houses. It was stated that there were 1,800 stand-pipes, with $\frac{3}{4}$-inch taps, belonging to the City of Glasgow Water Company. The number in Paisley was said to be about 600, and in Glasgow, south of the Clyde, about 200. With very few exceptions those which I myself saw were leaking to a considerable degree, and I feel satisfied that in numerous cases the leakage amounted to many times the supply required for the whole neighbourhood.

Mr. Mackain informed me that he had six men always employed in attending to these common taps belonging to the Glasgow Water Company, to see that they are in good order, and that the water is not allowed to run to waste, and yet it was found impossible to prevent it.

He also stated that the people would sometimes put a nail into the tap to keep it open, and that the water is thus left running under a head pressure for days together till it is discovered. It appears, also, that in several instances the new supplies have been transmitted through the old works, and doubtless a good deal of loss arises from this circumstance. All parties were agreed that the waste of water must be very great, but I could not ascertain that any remedy had suggested itself. Thus Mr. Mackain states that no less than 3,000 gallons per minute were required to be pumped into the mains of the City of Glasgow Water-Works to keep them charged during the night.

The quantity which passes into the mains of the Gorbals Gravitation

Dr. Sutherland. Company was said, by the superintendent at the water-works, to be about 150 cubic feet per minute during the night hours;* and into those of the Paisley Water Company about 70 cubic feet per minute. These estimates are exclusive of the supplies for storage at the various works; and as only a very small quantity can be drawn for domestic purposes in the dead of the night, I fear they must be set down as representing approximately the loss from leakage in the services.†

Under any system of water supply it would probably be always requisite to count on a certain amount of waste from carelessness; but surely, in the present state of engineering science, it is possible to effect such improvements in the distributary apparatus as to diminish greatly, if not altogether to prevent, the loss from leakage.

Another source of waste appears to proceed partly from defective filtration of the water, and partly from the deposit of oxydes from the iron mains. These causes act in a twofold way: the body of the water is not so clear as it ought to be, and the first portions drawn from the stand-pipes and taps are always more or less muddy; so that I found the people were in the habit of allowing the water to run for a short time before taking what they required for use, and that it was also found necessary to flush the mains very frequently in order to keep them clear of deposit. There is nothing in either of these causes of waste which might not apparently be easily remedied; for in the first place, no water should be supplied which is not perfectly pellucid and free from suspended matter; and, on the other hand, it is no doubt possible to coat the inside of the mains with some substance impervious to the action of water.

My own opinion, in reference to the ultimate cause of this waste, is, that it must be attributed to the practice hitherto followed of separating the distributary apparatus from the works of water supply. The water companies have taken the steps they thought best for obtaining an abundant and pure supply, and for laying down mains to convey it to the localities where it was required; but from this point the whole distribution has been conducted pretty much at hazard. There has been no oversight exercised upon the supply-pipes or taps, which are frequently of unsuitable construction and in a bad state of repair. It is true that powers generally exist enabling the companies to enter private dwellings and inspect the services, but practically they have not been exercised, and there is, so far as I know, no legal provision for insuring the use of any improved apparatus, however excellent. It may be truly stated, that at present the large supplies furnished to the towns which I visited are required, 1st, for *waste*; 2nd, for domestic supply. A small portion of the engineering talent which has been bestowed on the works would readily discover means for reducing the waste; and I have seen nothing in the whole of the inquiry which could justify the very high estimates which have been given as to the quantity required for absolute consumption. If the public are determined that the existing form of management shall continue, there appears to be no

* More accurate inquiries on this point are being made.

† I have been informed by Mr. M'Donald, the water inspector at Liverpool, that he recently discovered a wastage in a cellar, which, on a moderate calculation, had been discharging at the rate of 42,000 gallons a-day for the last 12 or 15 months.

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alternative but to submit to the loss, and to pay the very heavy local tax which it involves; but if an enlightened view of the question be entertained, and if it be really an object to obtain an abundant and cheap water supply for the poor, steps must be taken to secure the union of all portions of the works under one management, and to direct engineering talent to the improvement of the means of distribution.

The evidence adduced as to the small quantity of water taken for domestic purposes when it has to be carried, and the state of the interior of the houses, is quite sufficient to show that the system of constant supply from stand-pipes, although beneficial to a certain extent in a sanitary point of view, is by no means sufficient to effect all the improvement necessary in this direction. It is undeniable that houses into which the water had been conducted were very much cleaner than those into which it had to be carried by hand, notwithstanding that in both cases the supply was unlimited and constant. I conceive it to be indispensable to afford a constant water supply to every house. The water and soil-pipes are as much part of a house as the doors and windows; and nothing but that lamentable neglect of public duty which has delegated the important function of supplying the population of towns with one of the vital elements into the hands of private speculation could have led to the disjoining of the different parts of the same machine, thereby impairing the efficiency and increasing enormously the expense of the whole.

The evidence in the preceding pages appears to me to justify the following conclusions:—

1st. That the economic value of soft water for the supply of towns has been fully proved by experience.

2nd. That the use of soft water for all alimentary purposes is more conducive to health than that of hard water, at least among town populations.

3rd. That the estimated water supplies of towns have in many instances greatly exceeded the actual consumption.

4th. That under existing management the first and chief necessity to be provided for by water companies has been *waste* of the supply, while the domestic consumption has occupied in reality only a secondary position.

5th. That this waste originates partly in the disjunction of works which ought to be united under the same direction, and partly from defective nature of the services, and the small amount of attention which has hitherto been bestowed on their improvement.

I have the honour to be,

My Lords and Gentlemen,

Your obedient servant,

Liverpool, 22 *May* 1850. JOHN SUTHERLAND.

Philip Henry Holland, Esq., Surgeon, formerly of Manchester, examined.

Mr. Holland.

Your Report on the sanitary condition of Chorlton-upon-Medlock has been read by the Commissioners; and it is, moreover, understood, that you have been led to pay special attention to the question as to the water supply for towns?—I have; I took an active part in the inquiry for an increased supply and improved method of distribu-

Mr. Holland. tion of water for Manchester, and have taken great interest in the subject generally.

Where do you now reside, and with what water are you now supplied?—I reside at 74, Upper Stamford-street, Lambeth, and used to be supplied with water by the Lambeth Company. The water is, I understand, derived from the Thames near Waterloo Bridge; I now procure a supply from the Vauxhall Company. The water is taken from the Thames near Battersea, which is not quite so bad as that taken near Waterloo Bridge.

What is the usual quality of the Lambeth Company's water?—It is very hard, and so foul as to be quite unfit for drinking. It is often, nay generally, offensive, and in warm weather swarms with visible insects. Even when filtered, it is unfit for drinking, and is, as I believe, unwholesome. To render it fit to drink, I am obliged to add to it lime water, as recommended by Dr. Clark, which precipitates the chalk and much of the organic matter, and renders it less hard, and removes its unpleasant taste and smell.

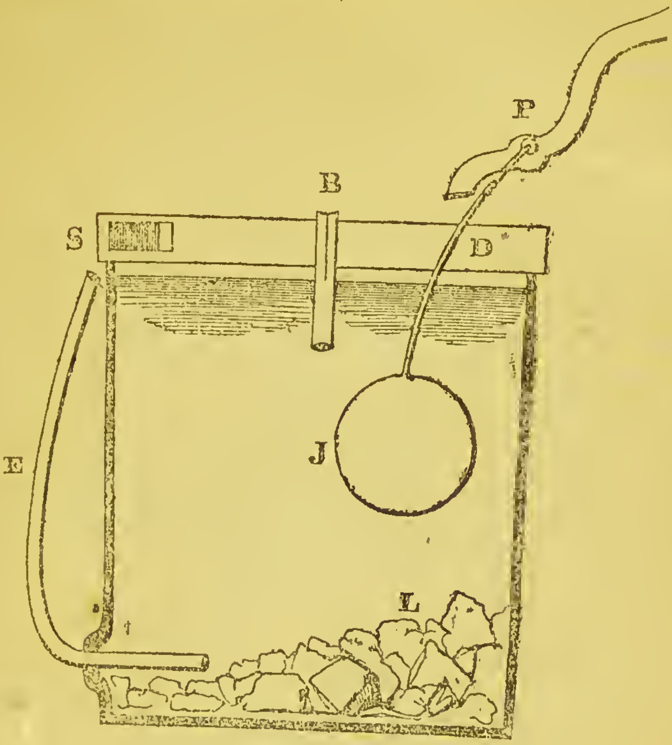
Is not this a troublesome process?—Not very, but it requires constant attention, and is apt to be neglected. It is very unjust for the Company to impose this trouble upon me; they charge an exorbitant price, and ought to supply a good article, instead of a liquid unfit for either drinking or washing with, until I do with it what the Company ought to do for me. It would increase their expenses but little to add the lime, and filter the water; but if all their customers do as I do, their total expenditure must be something considerable, and if they do not, they must suffer losses much more serious.

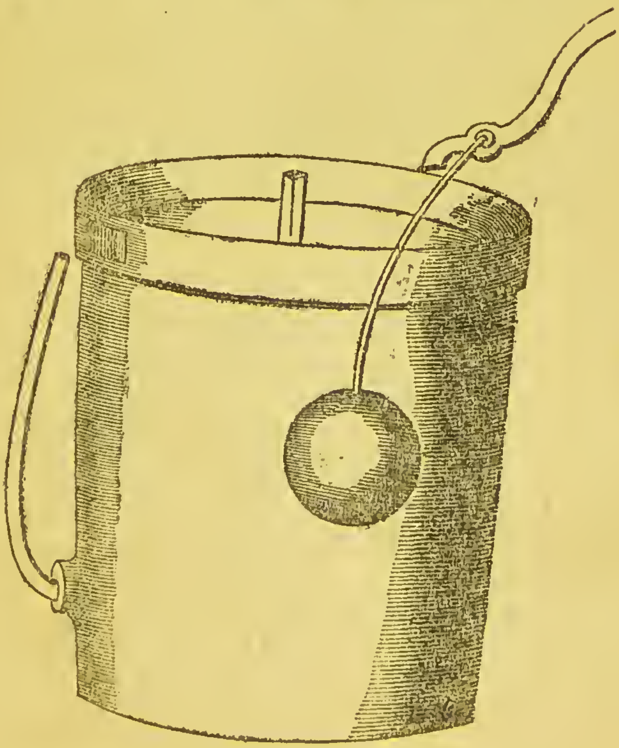
How do you mix the lime water?—I have two jugs, one holding 13 * times as much as the other. I fill the smaller one with a saturated solution of quick lime (lime water), put this quantity into the larger one, and fill it up with the water to be purified, and mix the two together; chalk is formed by the union of the bi-carbonate of lime in the water with the quick lime added; this falls slowly to the bottom of the jug, carrying with it most of the organic impurities; the clear water is filtered for use. To avoid this trouble, or rather to ensure the regular addition of the lime, I have constructed a simple instrument which mixes the lime-water for me, and requires no attention except adding fresh lime once or twice a month.

Describe the apparatus?—It is very simple, as may be seen from this drawing. J is the lime-water jar, which is placed in the cistern, with its top just above the water line; in this I put a few pounds of quick lime, which requires renewing from time to time. On the top of the jar is a zinc dish D, into which the water from the supply-pipe runs, and is stopped when the cistern is filled. This water entering is divided into two portions; one thirteenth part runs through the narrow notch in the pipe B into the jar. The rest runs direct into the cistern through a notch in the side of the dish, the width of which is regulated by the slide S. The water in the jar dissolves the lime, and entering at the top displaces an equal quantity of this lime-water from the bottom, which overflows through the pipe E, and mixes with the fresh water entering at S.

* The water has about 17° of hardness, and 14½° of alkalinity, and requires very nearly one-twelfth part of lime-water to be added to precipitate the dissolved chalk. This is rather more lime than the London water generally requires.

How is the proportion of lime-water to be added, regulated?—By the slide at S, by which the width of the notch may be increased or diminished, so that 12 times as much water may enter the cistern Mr. Holland.





directly, as enters the jar, which of course displaces an equal quantity of the lime water it contains. In order that the flow through the two notches may continue proportionate, whatever be the rapidity with which the water enters, the width of the larger notch diminishes up-

Mr. Holland.

wards, by which compensation is made for the increasing proportionate resistance to the flow through the narrower notch, as the dish fills.*

After the liming and filtering, is the Lambeth water a first-class water?—Certainly not, far from it. It is still hard, though much less so than before, neither is it so pleasant to drink as the bright sparkling mountain water with which Manchester, for instance, is to be supplied. Nevertheless it is not much to be complained of, and I have good reason to be grateful to Dr. Clark, for showing so easy a way of improving it so much.

Can you not improve the water still more?—Yes, for washing, by adding to it a little oxalate of ammonia or of soda. I use the former. This precipitates all the lime, and makes the water very soft.

Do you consider it worth while to take all this trouble, and to incur this expense for the sake of soft water?—Certainly, it is very well worth while; in fact, without liming, I consider the water quite unfit for drinking; though it varies in quality, it has generally a very perceptible taste and smell which the lime removes. Then as to softness; I am charged 35*s.* a year for water (which is far too much), but, however, water costs me say 8*d.* a-week, but the soap for my family, in addition to that for the washing sent out, costs about 1*s.* 6*d.* a week, or twice as much as the water. It is evident that by diminishing the hardness of the water, and thereby the waste of soap, I may easily save the amount of my water-rate in that article alone. Besides that, I can wash comfortably with the softened water, but I cannot do so with any quantity of soap with the water before it is limed, unless I have it boiled to precipitate the chalk, which process is more expensive and troublesome. I should, however, much prefer being supplied with a water fit for ordinary domestic purposes, and, if necessary, paying more for it, though I think the present charge exorbitant, even if the water were good, but outrageous considering the stuff which they supply.

Is not the water for Lambeth filtered at all?—I think not, for if a flannel bag be tied round the supply-pipe, it gathers a quantity of mud resembling that on the Thames bank, and having "a very ancient and fish-like smell."

Have you tried the difference of hard and soft water for cooking?—I have not made any accurate experiments except as to tea-making; I find that the water softened by means of oxalate of ammonia extracts the strength of tea almost twice as well as when hard. I had tea made with equal quantities of the leaf, and equal quantities of boiling water, with and without oxalate of ammonia. The infusion made with water softened by the oxalate, was stronger and better flavoured, and had to be diluted with the addition of 80 per cent. of hot water to bring it down to the strength of the other. It follows, therefore, that with the oxalate 10 parts of tea go as far as 18 without it.

Does that saving pay for the expense?—Over and over again; my tea costs me about 1*s.* a-week, if I can save eight parts out of 18, I can have as strong and better flavoured tea for less than 7*d.* a-week, being a saving nearly equal to the water-rate. It is not easy, however, to get

* Since the sketch was made, I have added a funnel to the apparatus, into which the lime-water and entering water flow, so that they may be more thoroughly mixed. I have also placed pieces of coke in the jar on which the lime rests, thus offering a large surface to the action of the water.

these savings effected regularly; it is apt to be forgotten, and cannot well be left to the servants. It would be far better to have a water originally soft, if it were procurable. Mr. Holland.

Is there any danger in using the oxalate of ammonia or soda?—Not the slightest with common care; the water does not require quite two grains of oxalic acid to the pint, to precipitate all the lime it usually contains. None of this remains in solution, and if a slight excess should accidentally be used, no harm is done, the neutral oxalates being innocent; nay even a small quantity of oxalic acid, if largely diluted, would be quite harmless.

How is the oxalate of ammonia prepared for convenient use?—By dissolving one troy ounce (480 grains) of oxalic acid in a quart of water, and adding as much carbonate of ammonia as will saturate it. Until the acid is saturated, the addition of the carbonate will be accompanied by effervescence; if somewhat more be added, it will be advantageous rather than otherwise. This quantity ought not to cost more than *3d.* and would soften above 30 gallons of water. A small teaspoonful of the solution is enough to precipitate the lime contained in a pint of Thames water; less, indeed, will be sufficient, if part of the lime be precipitated by previous boiling. More ought not to be added if the water is to be used for making tea, as more will give a taste like that of soot.

Do you recommend this mode of softening water for washing?—It answers very well; but I think the use of caustic soda still better, if cautiously employed. Common soda, which is a carbonate, is rendered caustic if a solution of it be shaken with some quick lime, which unites with the carbonic acid, and leaves the soda free. It must be kept from the air to preserve it caustic, and used cautiously, or the clothes will be injured by it.

Do these chemical expedients enable you to avoid the evils of hard water?—To some extent they enable those who have sufficient knowledge and care to avoid those evils. It is idle, however, to expect that the population generally can employ such processes as I have described, properly; or, even if they could, that they would do so regularly. It is evidently the duty of those who have to supply a large population with water, to procure the pleasantest, softest, and purest water which is obtainable at any reasonable expense.

What amount of supply do you consider desirable in proportion to the population?—I think all calculations based upon the present consumption in any city or town in England fallacious, as I have no doubt that the consumption of water will at some future period, not far distant, be far greater than it now is.

Can you state that the present generation will ever consume at the rate of 30 gallons of water each daily?—Probably not; recent investigations appear to prove that a large portion of the supposed consumption of water, on which that estimate was based, is really waste, which may be prevented; to that amount the estimates may be diminished, but the real consumption will gradually, and probably quickly, become far greater than it now is, and there should be the means of providing for it as it arises by extension of the supply. The consumption will increase greatly, when water-closets are universal and baths very general, as I trust will, before long, be the case. There are many purposes to which

Mr. Holland. water might be usefully applied, were it provided in sufficient abundance, for which it is now little used.

You allude to opinions as to the necessity of extra supplies for flushing the sewers and cleansing the streets?—Yes; or rather to providing such a current in the sewers as would render flushing unnecessary by preventing all deposit, and in assisting in the cleansing of the streets. It often happens that streets cannot be cleansed without the aid of water; and if it be attempted, that only about one-third of the dirt is removed by mere sweeping and scraping, the rest being impacted between or adherent to the stones. This is proved by the fact, that if streets, when the mud is very adhesive, be first well watered, three times as much dirt may be removed as would be if they are swept without water, allowance being made for the water contained in the wetted mud.

If some cheaper method of watering than by the cart were devised, would not much more water be thus used?—No doubt, very much more. There is no doubt either that, even without such improvement, much more water will be used for street cleansing than has hitherto been usual, for as the public learn by experience the great advantages of water-sweeping, they will insist upon its being practised; and very wisely so, for its advantages far exceed its cost.

Have you witnessed the operation of street cleansing by jet?—Yes, in Preston, Manchester, and London, but only by way of experiment.

Do you think it will supersede sweeping?—I do not think it will; but I have no doubt that the two might be advantageously combined, to a great extent, if water were supplied abundantly and cheaply, and at sufficient pressure to afford a strong jet. It would be very useful to wash the footpaths with the jet early in the morning.

What other public uses for increased supplies of water do you anticipate?—I think it very desirable that provision should be made for numerous public fountains, not only for ornament, but to provide water for horses, cattle, dogs, and other animals. Very serious evil is now suffered by animals, especially cattle, from the absence of drinking places. I have seen, as no doubt has everybody else, bullocks driven through the streets with their tongues covered with dust, stopping at every wet place in the road, hoping to find a mouthful of water, and almost maddened with thirst. Dogs also suffer severely; and with respect to horses it is a very serious evil. It is very common for a horse to be out all day without any water, except what his driver can beg or will buy; and often the carter is so indifferent to the sufferings of the poor animal committed to his care, that he will let him pass the whole day without water at all; this could hardly happen if drinking places were as common as they ought to be.

But would not such drinking places be themselves a source of inconvenience?—I think not seriously so, if they were made small, but numerous. A horse stopping to drink could cause no more inconvenience than by stopping for any other purpose; besides, we ought to submit to greater inconvenience than is at all probable to avoid the suffering and injury inflicted. We have no right to use animals for our use or convenience without taking due care to preserve them from unnecessary suffering. It would be easy at the same places to provide means for persons to drink, which would be a great convenience to the

poor, who cannot go into a shop to ask for water. I have no doubt such a provision would check drinking of intoxicating liquors very much. Mr. Holland.

What other new demands for water do you anticipate?—They are very numerous. For instance, if water were supplied constantly at high pressure, it would be used for washing windows, and possibly the fronts of houses. If, as is probable, ornamental house-fronts be introduced, made of tiles or non-absorbent bricks, the easiest way of keeping them clean will be by jets of water. The dingy, monotonous, and gloomy appearance of our streets is a very serious evil, which it would be worth making great efforts to remove. The good effect of external beauty and cheerfulness of appearance on the manners, temper, and character of a population is very certain; but we cannot preserve architectural beauty without cleanliness; and as there is no probability of keeping the air free from smoke (though much in that way ought to be done), we cannot have cheerful, handsome streets without the means of easily cleansing the house fronts. If such means were introduced, I have no doubt that external ornament would be more freely employed; probably variety of colour would be resorted to, if the colours could be preserved from being lost in the one universal hue of soot. In the suburbs of the metropolis it is probable that many individuals would have small ornamental fountains in their gardens if they could be easily and cheaply supplied, and so increase the demand for water.

Do you anticipate still further new demands for water?—Yes, many. For instance, at present many tradesmen employ very small steam-engines for purposes that may be almost as cheaply accomplished by hand, for instance, coffee grinding. There are many purposes for which steam might be substituted for manual power with advantage were it not for the cost of the skilled labour required to attend to it, and the expense and trouble of keeping up the steam when the power is not wanted. If some hydraulic engine, such as the tourbine, were employed, and worked by water from the pipes, which could be set at work and stopped in an instant, consuming no power except when at work, requiring no skilful mechanic to work it, and being quite free from risk from fire or explosion, there is no doubt that numerous applications of such power would be introduced which are, as yet, scarcely thought of. It would be easy to work cranes and hoists for raising and lowering goods and persons in warehouses, where the occasions for their use are not sufficiently numerous to make a steam-engine economical. Such an instrument would work presses in the smaller printing-offices where it is not worth while having a steam-engine. For many purposes a simple hydraulic press with a large cylinder acted upon by the direct pressure from the pipes would be sufficient for packing. In others, Bramah presses might be worked by the hydraulic engine. Turners might work their lathes, and smiths their bellows by water-power; chaff might be cut, and oats and beans crushed by the same means; in fact, it is impossible to mention all the various uses to which it might be applied, if water were supplied constantly and at high pressure. The little engines now used are sometimes procured rather to attract attention to their owner's shops, than for any economical employment of the power; the same end would be attained by engines worked by water pressure. I have no doubt that an extensive new trade will gradually grow out of the application of

Mr. Holland.
—— water-power to small purposes, when the system of constant service at high pressure shall be in operation in London, Manchester, and Liverpool, and the other great seats of industry. In order, however, that this may be the case, the supply must be ample and the charges to large consumers very moderate. I may mention that water-cranes are now in use at Liverpool and Newcastle, and are, I understand, economical even at the present charges of the Companies for water.

But with such charges could a fair income be derived by supplying water for these mechanical purposes?—No doubt of it. I have known a warehouseman pay 20*l.* a-year rent for the occasional power derived from a neighbour's steam-engine, for working his packing-presses. Many persons now employ little steam-engines which are uncertain, troublesome, and dangerous; if the same power were given by water without the trouble, uncertainty, and danger, many more persons could employ it than now use steam-engines, and the cost might be far less than that of the engines, and yet leave a handsome profit on the cost of procuring the extra quantity of water required.

What is the source of such economy? Does it not require as much extra power to lift the water required to work these hydraulic engines as they can possibly exert?—Certainly, more by the friction lost. But large engines are employed for pumping and small ones are got rid of, and the cost of a small engine is very great in proportion to the power it exerts, especially if it be not worked constantly; the cost of attendance, repairs, &c. being very great in proportion to the power. With simple hydraulic engines, on the contrary, no special attendance would be required, and there need be no expense incurred, except when the engine was actually at work. The supplyers of the water and the employers of the power would divide the resulting advantages, the former might sell this power (for small purposes and for only occasional uses) for much more than it costs, and yet supply the customer with power for such purposes cheaper than he could obtain it in any other way.

And you think there would be a large demand for water for such purposes?—No doubt of it. At a very small cost any persons wishing for the services of a one or two horse engine for an hour or two a-day, might have it without trouble, risk, or uncertainty; and there is no doubt that such an advantage would be very extensively used. Though the introduction of such novelties would, of course, be gradual, I do not think it would be very slow, if the charge for the power were not very much more than the cost of raising the additional water required and the expenses attending its distribution.

Have you known very serious domestic mischiefs produced by the insufficient supply of water?—I am not acquainted with the domestic life of the London population; but in Manchester the evils I have become acquainted with from want of water are of enormous magnitude. In that town a very large proportion of the population (in 1847 nearly one half) have their supply of water from pumps, the great majority of these get it from pumps which are kept locked up, except during a short time each day, consequently the supply procurable is very scanty. This scantiness of supply leads to great neglect of cleanliness; for instance, I have known the water used for washing a room kept to wash it with again and again, till it became dreadfully offensive. I have known persons come to their work unwashed, and

Mr. Holland.

wash themselves at their employers, because they had no water at home. I have known a man wash himself in water so offensive that it made his eyes sore, and I have frequently known the only water to be got to drink evidently and perceptibly polluted from some neighbouring drain or cesspool. It is impossible to doubt that such circumstances must debase a population and must render them prone to resort to beverage less disgusting. It is in short impossible to overestimate the importance of securing to the *whole* population an ample supply of pure water. A good water supply, ample in quantity, and universal in distribution, is an essential preliminary to sanitary improvement.

It is understood that you have given much consideration to the machinery by which sanitary improvements should be worked. Do you agree in the opinion that the control of the water supply and of the drainage should be vested in the same authority?—Decidedly, and for various reasons. In the first place not only are both proper water supply and proper drainage necessary for every inhabitant, but each is essential to the other; without proper water supply the drains are certain to become the receptacles of decomposing filth, and themselves sources of disease and danger, and without drainage, water supplied is apt to become a nuisance by causing dampness. Secondly, the works for bringing pure water into and carrying foul water out of the houses are more economically, and likely to be more effectually, constructed together than separately. Thirdly, though it is essential that water enough to carry away the filth be supplied, waste is injurious, not only because it requires more power to pump it in, but because much of it will have to be pumped out again if the lower sewers are to be kept clear at all times, and still more so when the sewage is used for agricultural reproduction. Those who will be most inconvenienced by the waste (*i. e.* those who will have to dispose of the sewage) ought to have authority over the supply, for which reasons, among others, the water supply and the drainage ought to be placed under the same authority.

Is it not also desirable that the paving and cleansing of the streets should be placed under the same authority as the water supply and drainage?—Such a consolidation of authority would be a source of greatly increased economy and efficiency. No one ought to be allowed to meddle with the streets except those appointed by the authority responsible for their proper condition. If, as sometimes happens, one authority direct the formation of the streets, another their repairs, a third their cleansing, a fourth their drainage, while a fifth and sixth are empowered to tear up the pavement for laying down and repairing water or gas-pipes, the public can have no security for such streets ever being in good condition. It is true that such extreme division of authority is not common, but it is possible, and to a greater or less extent, such injurious division of authority is universal. Where authority is divided responsibility is to a great extent destroyed.

Would there be any further public advantage from having all these matters under one and the same control, besides that of increasing the responsibility?—Yes, very great. If streets be properly made and kept in proper repair, less detritus is carried into the sewers, and less trouble and expense is incurred for keeping them clear; and if those who

Mr. Holland. have the control of the streets have also the control of the water and sewers, they may greatly facilitate and economise the proper cleansing of the streets on which their maintenance in good condition so much depends. Water might be economically used for cleansing to a very great extent, either with the jet or water-cart, if it were supplied at cost price, and if it were not for the cost of carting it away in the form of slop. This cost might be avoided by making arrangements by which the slop (produced by wetting the streets previous to sweeping) might be conveyed away through the sewers. There would be no danger of obstructing the sewers by shooting the slop into those only of large run, and the manure need not be lost, as the sweepings would add to the strength of the sewage. Of course the public would receive the advantage of any economy thus produced, either in increased comfort or diminished expenses, and many lay-stalls might be got rid of, and the nuisance of slop-carts in the streets avoided.

Are you aware of any serious inconveniences and disadvantages from the large number of different authorities having control over the various streets of the metropolis?—The disadvantages are very great. In many instances there is a very disproportionate expence incurred for superintendence; in others the officers are paid for part only of their time, and often are not paid such salaries as will secure men of sufficient education and knowledge. If the districts were larger it would be *evidently* worth while to secure for officers men of higher rank, who would devote themselves exclusively to their duties. Again, the great subdivision of London leads to great injustice. Suppose the inhabitants of one parish are desirous of having their streets in good order and clean, unless the adjoining districts concur a great and unjust expence is imposed upon the cleaner parish, because every vehicle which passes from a dirty on to a clean street carries dirt from the former to the latter, and renders cleanliness more difficult and expensive. Further, the inhabitants of London have an interest in the condition of other streets besides those of their own parish. Besides the inhabitants of Regent-street, for instance, all the riders in the 5,000 vehicles that daily pass through that great thoroughfare are affected by its condition, and the inhabitants of Regent-street, who have to bear the cost of keeping that street in good repair and well cleansed, *for others benefit as well as for their own*, may fairly feel aggrieved if they do not experience the benefits of good and clean streets when they go into other districts. It is evident that justice to all requires that in every part of London the streets should be kept in equally good condition, and as the indirect losses occasioned by their being badly paved or badly cleansed far exceeds the cost of keeping them in a proper state, it is to the interest of all that all streets should be well kept. This, however, never will be the case so long as there are the multitude of petty and uncontrolled authorities that now exist. Either one authority should be appointed, responsible for the condition of the whole metropolis, representing and acting for the whole, or the various local authorities should exercise their powers subject to the superintendence and control of a central authority. I have no hope that the present evils will be got rid of, without changing the system of local government (practically irresponsible) under which they have grown.

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1. You are a graduate in medicine of the London University?—I am a Bachelor of Medicine of the London University, and a Fellow of the Linnæan Society.

2. Have you directed much attention to subjects of natural history?—I have; to various branches of zoology and botany.

3. Have you directed your attention both to vegetation and to the animal life which accompanies vegetation in waters?—I have, and especially to the vegetation occurring in fresh water, upon which, in 1842, I published a distinct work, entitled "A History of the British Fresh-water Algæ," and which contains figures and descriptions of nearly 500 species.

4. In the course of your investigations have you examined many river waters?—I have examined the waters of the Thames, the Ravensbourne, the Lea, and the New River, also those of the rivers Colne and Wandle and the springs connected with these.

5. At what points have you examined the Thames water?—I have made a series of observations at various points between Kew Bridge upwards, and Woolwich downwards. I have also examined it at Brentford, Richmond, and at Henley-on-Thames.

6. At what points have you examined the New River?—I have examined the water of the New River at the Spring heads near Ware, at the reservoir at Cheshunt, and also as supplied to the public; obtaining it from the service-pipes of different cisterns.

7. At what points have you examined the Colne?—As the river passes through the town of Watford, and at the spring situated in the neighbourhood of the town.

8. At what points have you examined the Wandle?—At the large pond which receives the drainage of the town of Croydon, at the springs at Waddon, and also at Beddington, below Croydon.

9. What waters have you examined which may be called pure waters, to serve as a standard of comparison?—The waters of the deeper wells, and spring-water in general, these containing little or no living organic matter.

10. Have you examined any waters off the granite, or any surface-water?—I have not yet had an opportunity of examining any water off granite: I presume that the greater portion of the water of rivers is to be regarded as surface-water.

11. Have you examined rain water?—I have made several examinations of rain-water immediately after its descent to the earth, obtained in both town and country, and can confidently assert that it does not, in general, contain any form of living animal or vegetable matter: in procuring rain-water for microscopic examination, it is necessary, however, that certain precautions should be adopted in its collection; thus, the vessel into which it is to be received should be placed far away from houses or other buildings, and also raised some two feet above the surface of the earth; or otherwise, in some cases, the drops of rain will bring down from the roofs and sides of the houses sporules and filaments of *confervæ*, the ova of *infusoria*, &c., the former of which are frequently very abundant on damp walls, sheds, palings, trees, &c.

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12. Have you made any examination of the water of rain-butts?—I have examined the water of two butts, and that of one of them at two distinct periods; the first examination was made a week after its fall, in this I could not detect any trace of organic matter dead or living, while the second examination was made at the expiration of a fortnight; on this occasion I observed two or three extremely minute *infusoria*, probably *monads*, and globular bodies, possibly ova; the water of the second butt was also examined at the end of a fortnight, and its condition was as nearly as possible the same as that of the water of the first butt at the corresponding time.

Previous to the recent rains both butts were empty, otherwise the extent and variety of the living organisms presented would, no doubt, have been greater, as these wooden butts and vatts serve to harbour and greatly encourage, exposed as they usually are to light and air, the development of the lower forms of animal and vegetable life. I would now observe that every moving particle noticed in water must not be mistaken for a living production, as inorganic substances reduced to a certain state of division display active movements.

13. You would regard, then, rain-water as one of the purer waters?—Yes; as the purest of all water, except distilled water; and I would observe that the quantity of organic matter contained in the water of the two butts submitted to examination bore no comparison to that present in river water, being at least a hundred-fold less.

14. You are probably aware that it has been stated that waters caught out at sea in sails and casks have an appearance of visible animalculæ?—If the rain-water contained in the cask were in any degree exposed to the influences of light and air, it is very probable that, after a certain time, infusoria would become developed in it.

15. It has been stated that animalculæ are to be found in rain-water, however quickly it may be caught after its fall?—I should doubt the accuracy of the statement, it is opposed to my own observations; and it, moreover, appears to me that most animalculæ would not meet with in water, in a state of vapour or rain, the conditions necessary for their existence. Rain-water, just fallen, might indeed be readily conceived to contain in some cases the sporules of fungi, and the ova of infusoria.

16. But do not some rains bring down with them animalculæ?—In some cases, in different parts of the world, living productions, both animal and vegetable, have descended in showers of rain, but such occurrences are rare and exceptional.

17. Are you aware what difference it makes, as regards vegetable growth, whether the water is hard or soft?—I should not consider that that circumstance would occasion much difference in the amount of vegetation contained in water, this being more influenced by air, light, and rest.

18. As a general rule, does not this phenomenon occur if you expose water to air and light, algæ form rapidly?—Yes, the development of vegetable and animal life is essentially connected with free exposure to the influences of air and light.

19. The more rapid forms of vegetation occur repeatedly, decay, and then animal life appears?—Yes; such is the usual order of succession.

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20. Have you made any experiments for the purpose of determining accurately the effects on the development of vegetable and animal life, of the exposure of water to air and light, and also the effects of the deprivation of these agents?—Conceiving the determination of the effects of air and light on the development of the lower forms of vegetable and animal life to involve points of much practical importance in reference to the conveyance of water long distances, and to the system of reservoirs and cisterns, I have instituted, with the above view, several experiments, the more important of which I will proceed to relate in as brief a manner as possible, commencing with those which have reference to the *combined influences of air and light.*

Into a number of bottles filled with water, there were introduced living animal and vegetable productions appertaining to each of the principal classes of the lower forms of organic life, as follow: 1. *Entomostraceæ;* 2. *Infusoria*, the Thames *Paramecium*, and *Oxytricæ* principally; 3. Green *Infusoria* of the genus *Euglena;* 4. Filaments and sporules of green *Conferveæ;* 5. *Desmideæ;* 6. *Diatomaceæ;* 7. *Fungi.*

Examined at the expiration of a week, the several organisms, animal and vegetable, were found to be in a living state.

Again examined, at the end of five weeks, the various productions, with the exception of the Thames *paramecium*, were found not only to be in a living condition, but to have multiplied greatly, other species having made their appearance; this increase was particularly evident in reference to several species of *diatomaceæ* and the green sporules of *conferveæ*, these having increased to such an extent as to cause the water to assume the green hue of pond-water.

The Thames *paramecium* had disappeared, but the *oxytricæ* were abundant.

In the next experiments the *air was excluded.*

The same number of bottles were filled in the same manner as in the first experiments, but in place of being open to the air, they were corked and sealed. Submitted to examination at the end of the first week, the several productions were observed to be living, and the *entomostraceæ* and *infusoria* to be as active in their movements as ever.

Examined a second time, at the expiration of the fifth week, except in the case of the Thames *paramecium*, there was an evident augmentation in the number of living productions, this being most evident in respect to the *entomostraceæ*, *conferveæ*, and *desmideæ*, of the genera *scenedesmus* and *closterium*; the increase, nevertheless, was obviously not so great as in the previous experiments, where the productions were exposed to both air and light.

In the following experiments the *light was excluded*, but not the air. The same number of bottles were prepared as in the previous cases.

At the termination of the first week the several forms of animal and vegetable life were observed to be still in a healthy condition, the only change observable was in the green *infusoria* and *algæ*, which appeared of a paler colour than at first.

At the end of the fifth week the following changes had occurred: the *entomostraceæ* were dead, and the Thames *paramecium* could not be detected, but in the same bottle of Thames water there were present, in a living state, *annelidæ*, *oxytricæ*, *rotifera*, and a large blue *stentor;*

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the two last were not visible in the water when first placed in the bottle; the green *euglena*, *confervecæ*, and *desmideæ* were bleached and dead: no certain conclusions could be come to with respect to the *diatomaceæ* and *fungi*.

In the last experiments both *light and air were excluded.*

The results were nearly similar, but still more marked than in the former experiments; in the bottle filled with Thames water but a single *paramecium* was to be seen, but two or three *annelidæ* and several *oxytricæ*, and *rotifera*: the *rotifer* appeared to be of a different species to that present in the same water not excluded from the air, and there were in the last no examples of the blue *stentor*.

In no cases in which light was excluded could an actual increase in the number of living productions be ascertained, except in reference to the species of *infusoria* of the genera *stentor* and *rotifer*.

Although no special experiments were made with the *annelidæ*, yet the occurrence of these at the expiration of five weeks, in Thames water excluded from both light and air, shows with what tenacity the vital principle is retained in them.

From the preceding experiments the following conclusions may be deduced.

1st. That the combined influences of light and air favour, in a high degree, the growth and development of the lower forms of animal and vegetable life.

2nd. That for the limited growth and development of the majority of these forms, a partial exposure to air is sufficient, since many species increase and multiply in sealed vessels.

3rd. That light is decidedly necessary to the prolonged existence of the *entomostracæ*.

4th. That it is not less necessary to the green *infusoria* and *algæ*.

5th. That while many species of *infusoria* live for a long time deprived of light, there are other species, the development of which would appear to be favored by its abstraction.

21. Does not temperature effect the development of the more simple forms of vegetable and animal life?—Yes, very much so; common observation is alone sufficient to show the powerful operation of temperature upon the organic world; the chill and lifeless aspect of nature in winter, contrasted with the redundance of life in summer, air and water teeming with thousands of strange and harmonious forms of existence, must be apparent to the most superficial observer, however the various divisions of the organic world, even the lower forms, do not run an equal or precisely similar course.

Thus the green *algæ*, the *confervecæ* especially, are amongst the first productions to feel the influence of temperature, and many species on the approach of warm and genial weather start into life and activity with wonderful celerity, and again on the approach of the cold of autumn and winter as quickly die, and disappear for the most part.

The *desmideæ* and *diatomaceæ* are more hardy than the *confervecæ*, especially the *diatomaceæ*, and these may be found in great numbers all the year round, but still their proper season is the summer.

The *fungi* are one class of nature's scavengers, and their proper season is the autumn, that is, they are most abundant just when their

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services are most needed, viz., when dead and decomposing vegetable and animal substances most abound.

The green *infusoria*, as the several species of the genera *euglena*, *microglena*, and *cryptoglena*, &c., would appear to be equally susceptible of temperature with the *confervecæ*, and are most abundant in the spring.

While the *entomostraceæ* and *infusoria* in general are most abundant in the spring and summer, yet many species live in great numbers through the winter, this is the case with the Thames *paramecium*.

The *annelidæ* are very hardy, and are to be found abundantly in winter.

22. Have you tried the effect of boiling upon the *infusoria* and *algæ?*—I believe that the vitality of every kind of living production found in water in general is destroyed by the temperature of boiling water, the only question is in respect to the *fungi;* this is a matter, however, that might be readily put to the test of positive experiment. That the vital principle is destroyed in the great majority of instances by boiling is shown by the following experiment. Two bottles of boiled Thames water were put aside, and examined at the end of a week, the one having been exposed to the air, and the other corked, the only living production contained in either was a minute species of *infusoria*, probably a monad; and this was more abundant in the water exposed to the air than in that excluded from it. A second examination, made at the end of the fifth week, did not disclose the presence of any other organism.

In certain natural and boiling springs, living productions, animal and vegetable, have been noticed, but these are of different kinds to any of those met with in the waters usually employed for domestic purposes.

The skeletons of the *diatomaceæ*, being of flint, are not injured by boiling, and retain their forms, even in boiling nitric acid.

23. Is not the development of the lower forms of vegetable and animal life very much favoured, not merely by exposure to air, light, and temperature, but also by a motionless and stagnant condition of the water?—Yes; very much so; the abundance as well as the forms of vegetable and animal life which occur in water depend greatly upon its condition as to rest or motion: thus life is much more abundant in still than in running water, and the forms are different in the two cases; in old ponds, on heaths, amongst vegetation, we meet with the *desmideæ* principally, as well as numerous *infusoria;* in ponds, in fields and parks, not of such great extent as to deserve the name of lakes, we notice chiefly *confervecæ*, as well as certain *infusoria* and *entomostraceæ;* in lakes and ornamental waters but few *confervecæ* are present, but numerous *diatomaceæ*, *infusoria* of the genera *aneurea*, *brachionus*, *peridinium*, also *entomostraceæ* abundantly; the water of slowly running streams has no very distinctive character, but contains *diatomaceæ*, *confervecæ*, *infusoria*, and *entomostraceæ*, in nearly equal proportions, while that of the more rapid streams and rivers is remarkable for its comparative freedom from minute organisms, vegetable or animal, and those which do occur are of different species; thus amongst the *confervecæ* the principal species met with are *gladophora*, *glomerata*, and *lyngbia zonata*, both of which have roots.

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24. What is the depth at which aquatic vegetation will grow?—In the clear and transparent water of the sea vegetation will grow at a considerable depth, but still not beyond the influences of air and light, while in fresh water but few species are to be found growing more than a very few feet below the surface; this is in part due to its comparatively less transparency, and in part to other causes. Almost all the marine *algæ* are furnished with roots, by means of which they attach themselves to the rocks, while but few of the fresh water species are provided with any such organs; one of the reasons of this difference is obvious, the constant motion and agitation of the waters of the sea necessitate the provision of roots, which in still, fresh waters would be entirely useless. The second reason is less apparent; the function of respiration is one of the greatest importance in all plants, including the *algæ;* in the sea these are brought within the direct influence of the air at each period of the recession of the tide, and hence their attachment to rocks at a considerable depth below its surface does not interfere materially with the process of respiration or aeration; in still waters in general there is no tide, and the *confervecæ* rooted at the bottom of a pond or river would be removed constantly, and to a great extent, from the action of air, light, and heat, and this is the second reason why the fresh water *confervecæ* have no roots; they float, therefore, freely in the waters in which they dwell, now at the bottom, now on the surface, according to varying atmospheric conditions, thus when it is light and the sun shines the process of respiration is in full activity, oxygen is evolved; this collects in bubbles, which become entangled amongst the filaments of the *confervecæ*, causing them at length to become lighter than the water itself, and so occasioning their ascent to the surface, where they remain until night approaches, or a marked change in the weather comes on, when the gaseous bubbles having escaped into the air, and no renewed formation of them occurring, they become once more heavier than the water and again subside.

25. What would be the least depth, according to your observation or information, at which water ought to be stored in open reservoirs, *i. e.*, in reservoirs of too large a capacity to be roofed?—I should say not at a less depth than from 10 to 15 feet, and the deeper the better, the greater the depth of the water the less surface in proportion would be exposed to air, light, and heat, the circumstances favouring development. A large surface of water can scarcely be exposed freely to the above influences without its purity being more or less injured, nevertheless the abundance of vegetable and animal life in an open reservoir does not solely depend upon exposure, but is also closely connected with the condition of the water by which the reservoir is supplied. If it be not contaminated with sewage, and do not contain the sporules and ova of *algæ* and *infusoria*, I have but little doubt that water might be retained for a short time in an open reservoir in a pure and wholesome condition, almost, if not quite free from living organic matter.

26. What should be the speed per hour of water in shallow channels to prevent such growths?—Not less than from three-and-a-half to four miles an hour. I do not consider, however, that this speed would entirely prevent the development of the lower forms of vegetable and

animal life, but it would, no doubt, be sufficient, greatly to lessen their numbers and to modify the varieties. Dr. Arthur Hassall.

27. What length of time, in your opinion, may water be retained in an open reservoir without any material alteration of its purity?—That will depend very much upon the character of the water supplied to the reservoir, and on the management and state of the reservoir itself; if the water be of an impure kind. and contain either dead or living organic matter, or both, as in the case of Thames water, then it could be kept in the reservoir but a few hours without suffering a further deterioration, and the period would be still shorter if the condition of the reservoir was itself bad, and if the organic matter derived from the water were allowed to go on accumulating from day to day, week to week, and even year to year, as it is frequently allowed to do; where such is the case, there is at all times an enormous amount of putrescent organic matter present, capable in a very short time of seriously contaminating the water by the effects of its decomposition, and entirely independent of the pabulum which it affords for the sustenance of myriads of *infusoria*; but if on the other hand the water poured into the reservoir was of any of the purer kinds, as rain, spring, well, or even the purer river waters, previously filtered, and due attention were at the same time paid to the state of the reservoir, then I believe that any of these waters might be retained in it for many weeks without prejudice to its purity.

28. Have you made any experiments in order to elucidate the question of the stowage of water?—The effects already detailed of the exposure of water to the influences of air, light, and temperature are intimately connected with the stowage and conveyance of water, nevertheless, I propose to try the following experiments, and to place on the top of a high house six vessels, each capable of holding two gallons of water, the one to be filled with distilled water, a second with rain water, a third with water from a deep well, a fourth with well water and dead animal matter, a fifth with the same and vegetable matter, and the sixth with the same kind of water and a mixture of both vegetable and animal substances: the results of these experiments require time for their development, but their probable nature it is not difficult in some respects to anticipate.

29. Have you observed the Serpentine, or other ornamental waters, or canals, so as to be able to state, from observation of the vegetation, the condition of animal life contained in them?—I have examined the water of the Serpentine, of the large pond opposite Kensington Palace, and of the ornamental water in St. James's Park.

30. What was the condition of the water of the Serpentine?—I observed in it a considerable number of *diatomaceæ*, principally of the genera *surirella*, *exilaria*, and *navicula;* of *infusoria* of the genera *aneurea*, *brachionus*, *peridinium*, *euglena*, *rotifera*, and *polyarthra;* of *entomostraceæ* of the genera *lynceus* and *cyclops;* of *zoophytes* of the genera *hydra* and *alcyonidium*.

The condition of the water was worst at the Bayswater end, where the *diatomaceæ*, *oscillatoreæ*, and *rotifera* were principally found, while at the Hyde Park extremity the water was clear and bright, depositing but little sediment, but yet in each drop examined with

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the microscope numerous *infusoria* were in general to be detected.

The first microscopic examination of the water of the Serpentine was made early in the spring, and while the weather was still very cold, the particulars given above refer to its condition at that trial; since that period, however, matters have changed much for the worse in consequence of the increased temperature, and the amount of animal and vegetable life now present is many times greater, in particular the green matter which attracted so much attention a year or two since has again made its appearance in vast abundance. In reference to this matter I beg to introduce the following particulars, extracted, in part, from a communication which I have just prepared for the "London Botanical Society" on the colouration of the water of the Serpentine.

The sudden and periodical colouration of large bodies of water is one calculated to excite considerable interest, from the extent of the phenomenon, as well as from the mystery in which, to the common observer, it is generally involved.

The interest usually attending this phenomenon from the circumstances above referred to is enhanced in the present instance by certain important sanitary bearings.

The colouration of the water of the Serpentine is no new phenomenon, since it has been observed now for several years, and in fact has become annual.

Although many persons have expressed the opinion that this colouration is occasioned by a vegetable production, I am not aware that any observer has yet accurately determined its nature, or has given any description of the species which produce it. Dr. Tilt has even given a figure of a confervæ to the presence of which he considered that the colouration was due; the species represented by Dr. Tilt, is, however, very different from that which really occasions the phenomenon.

The production which undoubtedly causes the colouration belongs to the class algæ, is one of the family *Nostochineæ*, is the *Anabaina Flos. aquæ* of Harvey and myself, the *Dolichospernum Thompsoni* of Mr. Rolfs, and the *Coniophytum Thompsoni* of this communication.

Into the technical or scientific description of this production it is not necessary here to enter, it will be sufficient to notice the general facts connected with its presence in the Serpentine.

A month since, on walking round the Serpentine, I did not see a trace of this algæ; a week previous to first noticing it, which was on the 16th of June, I have been assured that not a vestige of it could be discovered. On the date referred to, the whole of the north bank of the Serpentine, from the bridge eastwards, was coloured of a deep æruginous or coppery green, the depth of colour increasing as the eastern extremity was approached. According to the evidence of one of the boatmen this extensive colouration took place in the course of one warm and sunny day.

On the occasion of a second visit made the following day, the distribution of the plant was much the same, only that it appeared to have increased greatly in quantity, and there was a vast accumulation of it at the eastern extremity, where the water was coloured as far as the eye could reach, the colouration extending to almost to the opposite side.

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Now this was not mere surface colour; a thickish pellicle of a vivid green, broken and variously streaked, floated indeed upon the surface, but the water beneath this was also deeply coloured, so that a bottle filled with it appeared of a bright metallic green hue; dogs, as they swam in the water, splashed up a green liquid; bathers, as they emerged from it, came up covered with this confervæ: the effect on the smaller fish, principally gudgeon, was remarkable; the plant, from its abundance and minuteness seemed to blind them, and the water where the algæ most abounded was kept in a constant agitation by their struggles, so that blinded as they were, numbers of them fell an easy prey to the eager children who were on the watch for them.

In order to form as correct an idea as possible of the quantity of this plant present in the water of the Serpentine, I took a boat from the boat-house situated near the centre of the north bank, and was rowed out into the middle of the river; a basin full of the water obtained there, presented a decided green hue; as the opposite bank was approached the colour entirely disappeared, so that in walking along this side of the Serpentine not a trace of the plant was to be seen.

The sudden appearance of this algæ is a remarkable fact in its history; another curious fact is its occasional equally sudden disappearance.

In what way are these phenomena to be explained? Is the sudden appearance of the plant in the first instance due to its exceedingly rapid development and growth, and its disappearance to its decay and dissolution? I think not; the gemination commences, I believe, beneath the surface of the water, and early in the spring; its diffusion through the water, and its ascent to the surface taking place at a later period, and being determined by temperature: on the first approach of warmth the plant rises and forms the green scum or pellicle already described, the quantity of which increases with the heightened temperature of summer: the immediate cause of the ascent is the respiration of the plant, and the disengagement of gaseous bubbles which render it specifically lighter than the water.

The disappearance of the algæ, which is sometimes surprisingly complete, is observed to occur in rainy, cold, and rough weather, and is due to its descent in the water occasioned by increased specific gravity, the result of impeded respiration, and the consequent absence of any disengagement of gas.

As already noticed, the *Coniophytum Thompsoni* is not equally diffused throughout the water of the Serpentine, but is limited to certain parts of it, and these are subject to much variation; this partial and variable distribution is dependent upon the sun, the direction of the wind, and the flow of the water towards the eastern extremity, which accounts for its very general collection in such quantity at that situation.

This variation, in some cases, is remarkable. On the 22nd instant, I walked all round the Hyde Park division of the Serpentine, and was astonished to find that the plant had apparently vanished, and that although so abundant scarcely a week since, not a trace of it was now to be seen, the weather at the same time being warm and sunny; in this case there were but two ways in which its disappearance could be accounted for apparently, the wind at the time being north-east, might

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have driven the confervæ through the arches of the bridge into the Kensington half of the Serpentine, or else at high water-mark it might have drifted over the water-fall, below which I observed a great accumulation of confervæ, &c.

The appearance and disappearance of the plant in question is especially deserving of notice, because it shows that in order to form a correct opinion as to the condition of the water of the Serpentine, it is necessary to examine it repeatedly; a want of knowledge of this fact might lead the observer into error, and he might conclude from not seeing it on the occasion of his first visit that the accounts given of its state were much exaggerated. These few observations complete the general description of the plant, and of the phenomena connected with its presence in the Serpentine; we have now to consider it in a sanitary point of view.

It may be safely assumed, I think, as a general rule, that the green or confervaed algæ when introduced into the system speedily perish without producing any ill effects upon the animal economy; this view is based upon the organization and requirements of this class of vegetable productions; there is, therefore, no reason to suppose that the species under consideration, if introduced by any accident, as in bathing, into the stomach, would be productive of directly injurious consequences.

The presence of this confervæ in such immense quantities in the water of the Serpentine has, however, certain indirect bearings upon health; thus many persons are deterred from bathing in the Serpentine, and it is very probable that those who are not so deterred do, in some cases, suffer injury; thus those who bathe in this green water emerge from it covered from head to foot with this plant; now, as it is not easy to remove it entirely from the skin, it is quite possible that in the efforts to do so some of the slender threads and minute cells become impacted in the cutaneous pores to the impairment of the functions of the skin.

There is, however, another view to be taken of the occurrence in such great abundance of this production more important than the preceding, viz., that where not hurtful itself, it is yet to be regarded as a test of impurity, and as an indication that the waters of the Serpentine are not at present in a wholesome or healthful condition.

The phenomenon of the colouration of large pieces of water by means of confervæ is by no means uncommon; several instances of such coloration have now been recorded, and the species to which the attention of this Society has been this evening directed, has once before been observed by Mr. Thompson, of Belfast, "floating like powdered verdigris on one of the small Locks Maben, Dumfrieshire." The most remarkable instance of the colouration of water from this cause hitherto recorded is that of the Red Sea, which, as is now well known, owes its colour and name to the presence of a minute and blood-red algæ.

I will conclude this communication by addressing a caution to the observer that he must not in all cases when he sees fresh water coloured of a vivid green conclude that the cause is some species of algæ, for the phenomenon is very frequently, and I believe most frequently, due to myriads of infusoria of the genera *Microglena*, *Cryptoglena*, and *Englena*.

31. What was the condition of the pond near Kensington Palace?—

Nearly the same forms of vegetable and animal life occurred in it as in the Serpentine, but altogether in greater numbers; the peculiarity of this water consisted in the presence of the Thames *paramecium*, which is explained, I believe, by the fact that the pond is supplied in part with Thames water, furnished by the Chelsea Company. Dr. Arthur Hassall.

32. What was the state of the ornamental water in St. James's Park?—It contained but few *diatomaceæ*, nearly the same forms of *infusoria* and *entomostraceæ* as the Serpentine, although in somewhat lessened numbers.

I would now observe that the condition of the several waters, the results of the examination of which are given above, closely resembles that of the waters of the numerous ponds belonging to or connected with the Hampstead Water Company, from which it appears probable that the state of other pieces of water of a similar origin and nature would not be found to be dissimilar.

33. As sources of supply to which would you give the preference, small or large rivers?—To large; the water of small rivers is for the most part drainage-water; it is easily contaminated, a single mill, or other source of impurity, being sufficient to affect the stream for its whole course; and, lastly, it contains the washings out of innumerable ditches, and which generally contain *diatomaceæ*, *conferveæ*, and *infusoria* in the greatest abundance. The water of large rivers is to be preferred for the following reason:—The greater part of the water contained in the bed of a river of any magnitude must have proceeded from considerable distances; now, water as it flows along purifies itself, the living productions contained in the nearly stagnant water of ditches, and which is apt enough for their development, transferred to the bed of a flowing river, become for the most part broken up, dead, and destroyed, deposited at the bottom of the river or dissipated by decomposition.

34. Do you find great varieties of vegetable and animal life in water?—I do; the number of distinct species which occur amounting to several hundreds.

35. What purpose do you suppose the *algæ* to perform in fresh water?—That of purifying and oxygenating the waters in which they are found.

36. Will you state, in popular terms, what you have found the variations in vegetable and animal life to be in different waters?—The purest description of water I have yet examined is rain water and that of the deeper wells and springs in general, in which I have found very little vegetable or animal matter in a living state. In the water of the shallower wells, in that of the Thames high up, and in the smaller rivers, which are not under the influence of the drainage of large towns, I have found both vegetable and animal productions, the former, however, predominating. But in the Thames, from Kew Bridge to Woolwich, animal life predominates amazingly. In other water exposed to similar deteriorating influences I have found the same forms of infusoria as in the Thames within the limits above referred to.

37. It is stated by Ehrenberg, as a general law, that where there is animal life in water visible to the naked eye, there is always a chain of animal life beneath it down to invisible existence. Have you found

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38. What species of infusoria represent the highest degree of impurity in water?—The several species of the genera *Oxytricha* and *Paramecium.*

39. What species is most abundant in the Thames from Kew Bridge to Woolwich?—The *Paramecium Chrysalis* of Ehrenberg; this occurs in all seasons of the year, and in all conditions of the river in vast and incalculable numbers; so much so that a quart bottle of Thames water obtained in any condition of the tide is sure to be found on examination with the microscope, to contain these creatures in great quantity.

40. Do you find that the infusorium of which you have spoken varies in number in the different parts of the river between Kew Bridge and Woolwich?—I find that it is most abundant in the neighbourhood of the bridges.

41. Then the order of impurity of Thames water, in your view, would be the order in which it approaches the centre of London?—Yes.

42. You find then, in Thames water, about the bridges, things decidedly connected with the sewer water, as vegetable and animal matter in a state of decomposition?—I do; about the bridges, and in the neighbourhood of London there is very little living vegetable matter on which animalculæ could live; the only source of supply which they have is the organic matter contained in sewer water, and which is to be regarded as the food of these creatures. Where infusoria abound, under circumstances not connected with sewage, vegetable matter in a living condition is certain to be met with. A knowledge of what constitutes the food of the infusoria has practical bearings upon the purity of water of no inconsiderable importance.

43. Then you regard the abundance of these creatures in Thames water as a clear indication of the presence of vegetable or animal matter in a state of decomposition?—I do.

44. May not their number then be taken as one test of the presence of noxious matter in the water?—Yes, certainly; and I should consider the test as a most unerring one.

45. What office would you attribute to the animalcules contained in impure waters, and especially in that of the Thames?—That of removing in the least injurious manner the organic matter contained in those waters. The infusoria are to be regarded in fact as one class of nature's scavengers.

46. Have you made any examination of the sewer-water with which the Thames is so largely impregnated?—I have examined the sewer-water of several of the principal sewers of London.

47. Will you state the results of your examination?—I found in sewer-water, amongst many other things, much decomposing vegetable

matter, portions of the husks and the hairs of the down of wheat, the cells of the potato, cabbage, and other vegetables, while I detected but few forms of animal life, those encountered, for the most part being a kind of worm or anælid, and a certain species of animalcule of the genus monas. Dr. Arthur Hassall.

48. How do you account for the comparative absence of animal life in the water of most sewers?—It is doubtless to be attributed, in a great measure, to the large quantity of sulphuretted hydrogen contained in sewer-water, and which is continually being evolved by the decomposing substances included in it.

49. Have you any evidence to show that sewer-water does contain sulphuretted hydrogen in such large quantity as to be prejudicial and even fatal to animal life?—With a view of determining this question, I made the following experiments:—1st Experiment. A given quantity of Thames water, known to contain living infusoria, was added to an equal quantity of sewer-water; examined a few minutes afterwards the animalculæ were found to be either dead, or deprived of locomotive power and in a dying state. 2nd Experiment. A small fish placed in a wine glass of sewer water, immediately gave signs of distress, and after struggling violently, floated on its side, and would have perished in a few seconds, had it not been removed, and placed in fresh water. 3rd Experiment. A bird placed in a glass bell-jar, into which the gas evolved by the sewer-water was allowed to pass, after struggling a good deal, and showing other symptoms of the action of the gas, suddenly fell on its side, and, although immediately removed into fresh air, was found to be dead. These experiments were made, in the first instance, with the sewer-water of the Friar-street sewer; they were afterwards repeated with the water of six other sewers on the Middlesex side of the river, and with the same result, as respects the animalcules and fish, but not the bird; this, although evidently much affected by the noxious emanations of the sewer-water, yet survived the experiment.

50. Would you infer from these experiments that sewer-water, as contained in the Thames near to London, is prejudicial to health?—I would, most decidedly; and regard the Thames in the neighbourhood of the metropolis, as nothing less than diluted sewer-water.

51. You have just stated that you found sewer-water to contain much vegetable matter, and but few forms of animal life; the vegetable matter you recognised, I presume, by the character of the cells composing the several vegetable tissues?—Yes; as also by the action of iodine on the starch of the vegetable matter.

52. In what way do you suppose these various vegetable cells, the husks of wheat, &c., reach the sewers?—They doubtless proceed from the fœcal matter contained in sewage, and not in general from the ordinary refuse of the kitchen, which usually finds its way into the dust-bin.

53. Sewer-water, then, although containing but few forms of animal life, yet contains, in large quantities, the food upon which most animalcules feed?—Yes; and it is this circumstance which explains the vast abundance of infusorial life in the water of the Thames within a few miles of London.

54. Did you notice any other matters in sewer-water besides those

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which you have already mentioned?—I did; a black carbonaceous-looking matter, upon which the inky colour of sewer-water depends, and portions of an ochreous substance, having much resemblance to muscular fibre.

55. Do you know the nature of this black matter?—The abundance of this black substance in the worst examples of sewer-water strongly excited my attention; I have, however, formed no very exact conclusions respecting it, but I cannot help entertaining the suspicion that it is really carbonaceous, the carbon of the organic matters contained in sewer-water being precipitated by certain spontaneous chemical changes. A similar inky substance may frequently be stirred up from the bottom of old ponds containing organic matter.

56. Were you able to ascertain the nature of the ochreous matter contained in sewer-water?—This at first puzzled me a good deal; I have, however, I believe, succeeded in determining its nature in a satisfactory manner. I have already remarked upon its resemblance to muscular fibre, this as well as the absence of any marked results from chemical re-agents, have satisfied me of its organic nature, and the non effect of concentrated sulphuric acid proved to me that it must be an animal substance. This suggested the idea of submitting human fœcal matter to a microscopic examination, and in this I immediately detected the yellow matter in question in abundance, and in a more perfect state than it is usually met with in sewer-water. It is to it that the fœces mainly owe their colour. I conclude, then, from these several observations, that this yellow matter is really altered muscular fibre tinged with bile, the presence of which in it is shown by the action of nitric acid, which causes it to give out the pink tint characteristic of that fluid. I detected, moreover, in fœcal matter fragments of the husks and hairs of the down of wheat; these last bear some resemblance to animal hairs, but are much smaller.

57. Did you find sewer-water to contain much animal matter in a state of solution?—I did, a great deal.

58. Did it occur to you to submit sewer-water to a chemical as well as a microscopic examination?—It did; I detected in sewer-water the colouring matters of the urine and of the fœces, evidences of the presence of urea, (an effete animal substance,) much sulphuretted hydrogen, and several salts in large quantities, as chlorides, sulphates, phosphates, and carbonate of ammonia. The chlorides, sulphates, and phosphates, were in part, no doubt, derived from the urine and the carbonate of ammonia, in part from the decomposition of the urea of the urine. On evaporating drops of sewer-water on slips of glass, it was curious and interesting to observe the occurrence of forms of crystals common in the urine when thus treated. The addition of nitrate of silver to sewer-water produces a remarkable effect, the soluble organic matter, the sulphuretted hydrogen, the chlorides, and the phosphates are all thrown down, a fluid clear and colourless as pure water alone remains, containing principally the sulphates and the carbonate of ammonia.

59. Have you detected in Thames water the various matters which you have described as present in sewer-water?—I have, repeatedly; particularly the altered muscular fibre, the potato and other vegetable cells, and the husks and hair of the down of wheat.

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60. Have you made any examination of the water of those companies which take their supply from the Thames?—I have.

61. And can you detect contamination by sewage in them?—I can, distinctly.

62. In what condition did you find the waters of those Companies which take their supply from the Thames?—Very bad indeed; some of them as bad as it was possible to conceive any waters used as a beverage could be; they abounding not merely with dead organic matter, but also with living animal and vegetable productions, *entomostraceæ*, *infusoria*, *annelidæ*, *conferveæ*, *desmideæ*, *diatomaceæ*, *fungi*, *&c.*

63. You did not, I presume, find the waters of all the Thames Companies equally bad and abounding to the same extent with animal and vegetable life?—No; for although the waters of all the Thames Companies were in a very impure state, yet marked differences were observable in the degree of impurity and in the characters of most of them. Thus the waters of those Companies which supply the Surrey side of the metropolis, as the Lambeth, Southwark, and Vauxhall, are in a far worse condition than those of any of the remaining Companies; the water of the Chelsea and West Middlesex Companies holds an intermediate position, although still very impure, while that of the Grand Junction Company, bad as it is, is yet the best of all the Thames Water Companies.

64. What were the characteristics of the water of the Lambeth Company?—The number of living productions contained in the water of this Company was very great indeed; but it was principally remarkable for the vast number of the Thames *paramecium* present in it, a circumstance explained in part by the fact that this Company takes its water from the river where those animalcules are very abundant, and in part, I believe, by the further fact, that it does not adopt any method of filtration, but delivers the water to the public in nearly the same state in which it is procured from the river.

65. What was the condition of the water of the Southwark and Vauxhall Company?—Equally bad, if not even still worse than the former; the living contents were not less abundant, although somewhat different in kind: thus while there were a great many Thames *paramecia*, there were also a considerable number of *actinophrides* and *annelidæ*, clothed with spine-like hairs; the former being most abundant in the water supplied to the district of Southwark, and the latter in that furnished to the inhabitants of Vauxhall. It is to be remarked that the *actinophrydes* occur likewise in the water of the Lambeth and Chelsea Companies, as well as in that supplied to Vauxhall, but not in the same numbers.

66. How do you account for the water furnished by the same Company thus differing in its living productions?—Although now united into a single Company, at one time the Southwark and Vauxhall formed two distinct Companies; and in this circumstance we probably find the explanation of the differences indicated by the microscope. The fact of their having been once distinct implies the possession of separate works and reservoirs, and probably a different system of management. I would here observe that the many forms of infusorial life encountered in the waters of the Metropolitan Companies which derive their supplies from the Thames, although the *paramecium*, so

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often referred to, is the most abundant and characteristic form, are yet all derived from Thames water.

67. You have stated that you detected matters connected with sewage in some of the Thames Companies, what was the nature of these matters, and in which of the Companies' waters did you detect them?—I have detected on several occasions, in the waters of the Lambeth and Southwark and Vauxhall Companies, matters connected with sewage, as the fragments of muscular fibre tinged with bile, black carbonaceous matter, and portions of the husks and hairs of the down of wheat, cells of potato, granules of starch, &c.

68. What was the state of the water of the Chelsea Company?—Better than that of any of the preceding Companies. The same forms of infusorial life were, however, present in it, but in greatly reduced numbers, a circumstance explained by the fact that this Company adopts a more efficient process of filtration, but one still not entirely or sufficiently effective, since living productions, and especially bunches of brown ova cases, are present in it after filtration.

69. And the West Middlesex Company, how have you found its water, as delivered to the houses?—Less free from living organic matter even than that of the Chelsea Company; it contains, amongst other productions, numerous Thames *paramecia.*

70. And the water of the Grand Junction Company?—Notwithstanding that this Company filters its water, I have yet found it to contain a considerable number of living animal and vegetable productions, but not in general the Thames *paramecium*, which is accounted for by the fact that this Company takes its supply from just above the usual limit of the distribution of this animalcule; the water of this Company, therefore, loses one of the chief characteristics of excessive contamination by sewage, and approaches more nearly in its condition that of rivers in general.

71. What have you found to be the state of the waters of those Companies which have a source of supply different from the Thames?—Very bad, but still their condition has been much better than that of all the Thames Companies, with the exception of the Grand Junction.

72. What was the condition of the water of the New River Company?—I found in it a few *entomostraceæ* and *infusoria*, but a great many *diatomaceæ.*

73. How do you account for the abundance of *diatomaceæ* present in this water?—In all slowly running rivers the *diatomaceæ* are very abundant; now New River water is not as is generally supposed spring water, but is composed in great part of water derived from the river Lea, and is conveyed to London at a very slow rate by means of a long and open canal, a circumstance which is therefore highly favourable to the development of the *diatomaceæ* especially, as well as other forms of microscopic life.

74. What was the state of the water of the East London Company?—It presented many of the characters of New River water, but also a greater number of *infusoria*, which is probably to be explained by the circumstance that the Lea is exposed to some extent to contamination by sewage.

75. As to the water of the Hampstead Company?—The water of

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this Company abounds with *entomostraceæ* and *infusoria* of the genera *aneurea*, *brachionus*, and *peridinium*, the species being similar to those contained in the large ponds from which this Company draws its supplies. There can, consequently, be no doubt whatever as to the source of the animalcules contained in the water of the Hampstead Company as supplied to the public.

76. And the Kent Company?—The water of this Company contains a considerable number of *infusoria* and *diatomaceæ*, and presents an average example of the waters of small rivers, such as are not protected from the public, the banks of which are not kept free from weeds, and into which are poured the contents of dykes and ditches, &c.

77. Are these several results founded upon repeated examination? —Yes; upon repeated examination. I have made several hundred microscopic examinations of water, of the principal results of which I have in general preserved notes. The water of the several Companies submitted to examination was obtained from the service pipes of different cisterns; it was therefore in the precise condition in which it was supplied to the public. It is to be remarked, that the above details and descriptions refer to the condition of the water during the winter and early spring months; in the warm weather of summer the state of the water would, no doubt, be much worse, the lower forms of animal and vegetable life would be more abundant, and the kinds in many cases different.

78. Will you state the determining causes, whether ingredients in the waters, or nature of the aqueducts, reservoirs, &c., or other circumstances on which the development of the different classes of animalcular and vegetable productions, in your opinion, depends?—The circumstances specified in the question, as well as some others not mentioned, all influence and determine, not merely the kind but also the quantity of animalcular and vegetable life present in the waters of the several London Companies. Thus "ingredients in the waters," as the various organic matters connected with the sewage contained in the Thames, determine the presence in Thames water of certain forms of infusorial life and the abundance of other forms, as the *paramecia*, *vorticellæ*, *actinophrydes*, *oxytricæ*, *uvellæ*, *&c.* The same ingredients determine also, it is most probable, the presence of the *annelidæ* in large numbers as Thames water, as also undoubtedly the *fungi*, which generally abound wherever organic matter is abundant. The comparative absence of vegetable life, especially of the coloured and green species, in Thames water near to London, is remarkable, and is accounted for probably partly by reference to the deleterious quality of the water, but is the result principally of the incessantly agitated condition of the river, occasioned by the numerous steamers which are constantly moving up and down on its surface. Now, as is the water of the Thames, so must, to a greater or less extent, be that of the water of those Companies which derive their supplies from the Thames; and we have already seen that this is really the case, and that the water of all of these Companies differs only from Thames water according to the particular part of the river from which its supply is derived, and the extent of the processes of purification adopted; thus the water of the Lambeth Company, taken from the part of the river where the Thames *paramecium*

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is very abundant, and no process of filtration being adopted, differs but little in any respect from Thames water near to Lambeth, and swarms like it with *paramecia.* The water of the Chelsea Company, inasmuch as it is filtered, is freed to some extent of its impurities; but yet a microscopic examination renders sufficiently manifest the nature of its source, and in it we likewise discover the particular species of animalculæ so characteristic of Thames water. In the water of the West Middlesex Company, again, we meet with numbers of the Thames *paramecium*, as well as other *infusoria*, but not nearly in the same proportion as in the Lambeth or Southwark and Vauxhall Companies, because these do not exist in the part of the river from which it draws its water in nearly the same quantities as at Lambeth. Again, in the water of the Grand Junction Company the *paramecium* is almost lost.

Other differences in the kind and quantity of animalcular life depend not merely upon temporary storeage in reservoirs, but also upon the condition of these as to cleanliness; if they contain much mud or sediment, and accumulation of organic matter, then we may look for the presence, in abundance, of minute *annelidæ* or worms, and it is probable that this is really the explanation of the great numbers of these creatures present in the water supplied to the Vauxhall district.

Then again we have seen that all small rivers, canals, and aqueducts abound with *diatomaceæ*, and hence it is that we find so many of these productions in the water of the New River, East London, and Kent Companies, especially the first.

It has been shown, also, that large pieces of water are favourable to the development of the *entomostraceæ*, and certain of the larger *infusoria*, owing, probably, to the absence of any decided stream or current in them, the waters being, in general, still and tranquil; and herein is the reason of the abundance of these animalculæ in the water furnished by the Hampstead Company.

The above are some of the principal circumstances favouring the development of different kinds and quantities of animal and vegetable productions in different waters; others are met with in the degree of exposure of the water, and the length of time it has been retained in the reservoir; these two circumstances operating in combination would determine, not merely an increase in amount of the living contents of the water, but would, probably, cause certain species to obtain a predominance.

79. Have you made any examinations of cistern water?—I have, many. A cistern is a small reservoir, and has all the faults of reservoirs; the water contained in it is generally exposed to light, air, and the sun, and the dead and living organic matter, as in the case of the reservoirs, too often goes on accumulating from day to day, the former seriously contaminating, by decomposition, the purity of its water: the living organic productions present in the water of cisterns resemble those of the water of the company by which it is supplied; certain forms, however, become developed in the water of cisterns with great rapidity, as the *entomostraceæ*, especially *cyclops, quadricornis, lynceus longirostris, daphnia quadrangula, infusoria, confervæ*, and *diatomaceæ;* the *entomostraceæ*, and some of the *infusoria*, swim freely about in the water, while the *confervæ*

and *diatomaceæ* either adhere to the sides, or else fall to the bottom of the cistern, together with the grit and dead organic matter, forming an ever increasing mass, which is stirred up on each renewal of the water only to subside in still greater quantity, until after the lapse of weeks, months, or even years, some fortunate accident, or frequently the offensive and putrid state of the water causes the cistern to be cleaned, and a removal of the putrescent and noxious matter. On making inquiries as to the frequency with which cisterns are cleansed, I was astonished to find how generally they are neglected; a neglect which is to be explained partly by ignorance of the necessity which exists for repeated and careful cleansing, and partly by the inconvenient and absurd position in which cisterns are very generally placed, mounted high up, frequently just over the privy or closet, and often requiring ladders to reach them; but the evils of cisterns are not merely aggravated by neglect and bad management, there are faults of construction connected with them; thus the bottom is usually level, and the tap inserted about two inches above this level, leaving a space for the continued accumulation of grit and dead and living organic matter; this evil might be obviated by having the cistern of a rounded form at the bottom, the discharge pipe issuing from the centre. Lastly, the material of cisterns is bad; they should be made of glass, earthenware, or marble.

80. You have already given the results of your examination of New River water as delivered to the houses, but what difference did you find in the water from one end of the river to the other?—The water in the little stream or ditch which flows into the New River Head, and which assists in supplying it, is in a very bad condition, and abounds in *infusoria* and *algæ*, especially species of the genus *rotifer* and the *diatomaceæ*. The state of the water in the head itself, inasmuch as it receives all the water from the feeding ditch, cannot be much more satisfactory; the margins of the pool or basin forming the head are covered with *algæ*, rising up into the water like clouds, and affording a nidus for the shelter, growth, and development of the *entomostraceæ*, *infusoria*, &c. The canal or river itself is at the present time* in a much better state than I have ever seen it before, but the quantity of *oscillatoreæ* and *diatomaceæ* which float on its tranquil surface during the warm weather of summer is immense, and must seriously affect the condition of the water. At Cheshunt the New River Company has a well worked by a steam-engine, and two reservoirs; the one of these reservoirs at least contains something more than pump-water, it being fed by a small stream, nearly dry in summer, but which in rainy weather contributes as well as the pump a fair supply of water. Well, the state of the water in these reservoirs at present is not very bad, but few *entomostraceæ* and *infusoria* being yet contained in it; this is accounted for by the fact that these reservoirs have very recently been cleaned out, and certainly the operation was much wanted, as I was given to understand that it had not been once performed before since the reservoirs were made, nearly twelve years since. The cleaning out of these reservoirs occupied nine weeks, employed thirty horses, and not a few labourers; the matter

* Early in May.

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removed consisted of a black muddy substance of an offensive smell, and similar in nature to that contained at the bottom of old ponds, and also to that which has recently been taken out of the Serpentine; this black mud contains much organic matter, of which fact those who removed it seem fully aware, as it has been spread over a field near to the reservoirs, and to the fertility of which it will no doubt greatly contribute. Some years ago the waters of the Cheshunt reservoirs were in a less pure state than at present, and were a frequent resort of mine, for on turning to my "History of the British Fresh-water Algæ," I find them given as the habitats of several species. Just below the head, the stream of the New River is joined by a second stream, apparently larger and more considerable, which comes from the River Lea. New River water is therefore a mixture of ditch, spring, river, well, and possibly in some cases of Thames water, as the New River Company has a communication with the prolific source of London water supply, the Thames, at Broken Wharf, Upper Thames-street.

81. Does the number of living productions in New River water equal those you found in the Thames, with the exception of those which you think are connected with sewage?—I should say that it contains as many living productions as Thames water does, taken above Richmond.

82. What was the condition of the water of the Lea?—I am inclined to think that the water of the Lea contains a larger number of *infusoria* than that of the New River. I examined its state more particularly in the canal of the East London Water Company, and found a very great many *diatomaceæ* and *infusoria*, principally of the genera *exilaria*, *diatoma*, *asterionella*, *coleps*, *oxytrica*, *bursaria*, and *amphiliptus*. Now it is from this canal that the East London Water Company professes to derive all the water which it requires, and yet it has a communication with the Lea, below Lea Bridge, at Old Ford, near to Stratford, and within the influence of the tide of the Thames, the water of which is still further contaminated by the many impurities of Blackwall Creek. I may here be permitted to state that further particulars in reference to the source, &c., of the River Lea, among other facts connected with the subject of water in general, will be found in a little work which I have recently published, entitled "A Microscopic Examination of the Water supplied to the Inhabitants of London. Illustrated by coloured plates."*

83. What are the indications as to the waters of the Wandle?—The river Wandle has a double origin; the one in a large pond situated in the town of Croydon, the other in springs at Waddon, near to Croydon. The water of the inner, or first spring, is remarkably free from living organic matters; that of the second spring contains numerous species of the lower forms of vegetable and animal life, and this is accounted for by the weedy and uncleaned condition of the borders of the spring or pond, while that of the third spring is still more contaminated with vegetable and animal life, it not merely being in a foul state, but receiving a small stream, which carries with it various impurities from the pond at Croydon. The pond situated in the middle of Croydon receives much of the sewage of the town, the refuse of gas

* Highley, 32, Fleet-street.

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works, a tan yard, and, I believe, also of a knacker's yard; its water teems with algæ and infusoria of the most impure kinds.

84. In what state was the water at Beddington, below Croydon?—It was found to contain many of the same forms of animal and vegetable life noticed in the pond at Croydon, and the same productions could be traced, by means of the microscope, at various points lower down the stream, even to Wandsworth, where it joins the Thames.

85. Have you tried the deep wells of London?—I have; the waters of the deeper wells are, in general, very free from living organic matter.

86. Have you made any investigations on the subject of the aeration of water?—I have.

87. To what is the presence of aeriform substances in water attributable?—To a remarkable power possessed by water to absorb and condense many of the gases in contact with or near to it, and which power is so great as to enable it to take up many times its own volume of certain gases.

88. What are the circumstances which regulate and determine the actual amount of the gases present in water?—The degree to which the air is charged with these gases, and the temperature of the water; the gases usually present in the air are ammoniacal gas, nitrogen, carbonic acid, and oxygen; the greater the quantity of these in the air, and the lower the temperature, the larger will be the quantity of gases absorbed. It is to be observed, however, that certain gases are sometimes present in water, as the sulphuretted, carburetted, and phosphuretted hydrogen gases, and which are not derived, in general, from the air, but from decomposing substances contained in the water.

89. Can you refer to any simple experiment proving the absorption by water of aeriform substances?—If water deprived of all gases, as distilled water, be exposed to the air, and tested after the lapse of a day or two, it will be found to have taken up an appreciable quantity of carbonic acid and oxygen; the same will happen if water be placed under a bell-jar, in contact with sulphuretted hydrogen; breathing through water is also sufficient to saturate it with carbonic acid.

90. Does the amount of oxygen contained in the atmosphere vary much?—Not so much as might be supposed; that is to say, the air of a large town has been found to contain nearly as much oxygen as that of the open country; the injurious effects on health of the air of cities is due, therefore, not so much to the deficiency of oxygen as to admixture with many deleterious contaminations; this nearly uniform composition of the atmosphere in town and country is the result of the operation of the law of the diffusion of gases, a law by which hundreds of lives are probably daily saved; in confined spaces, however, as in rooms, theatres, assemblies, where the law could not come freely into action, the quantity of oxygen present would be greatly deteriorated by respiration.

91. The quantity of oxygen present in water is, therefore, in your opinion, not subject to any great variation?—Not at *equal* temperatures; at *unequal* the variation is very great.

92. Is the variation of the temperature of water under common circumstances sufficient to occasion differences in the quantity of gases present; as, for instance, when it is exposed to the sun or the warmth

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of a room?—Decidedly so, the warmth of the sun's rays, or of a close room, are quite sufficient to occasion the expulsion of the greater part of the oxygen and carbonic acid present; and by boiling, the whole of these and other gases may be driven off.

93. The exposure then of water used for domestic purposes to a high temperature is prejudicial to its salubrity?—Yes, unquestionably; the oxygen and carbonic acid is thrown off, and hence the flatness and insipidity of the water: the oxygen expelled from water by the heat of the sun is, however, re-absorbed during the night, when the temperature is low.

94. Does the quantity of carbonic acid present in most water vary much?—Yes, a good deal; I have instituted a variety of experiments, intended to prove the absorption by water under more or less common circumstances of carbonic and in different proportions. These experiments are, however, not yet completed.

95. You have mentioned sulphuretted hydrogen as amongst the gases occasionally met with in water, have you detected it in any water now used as a beverage?—I have repeatedly, in Thames water, in the neighbourhood of the bridges; indeed on no occasion have I failed to find it.

96. What was the method of proceeding adopted?—I added to a wine glass of water a few grains of acetate of lead; this, after an hour or two, formed a precipitate at the bottom of the vessel of a brownish colour, a sulphuret of lead; in order to render the tint of the precipitate more evident, it is advisable to add a little of the lead to some water not suspected to contain the gas in question, and to contrast the two. The sulphuretted hydrogen might still be unequivocally detected in many cases in the Thames water, even after filtration.

97. The presence of sulphuretted hydrogen in Thames water, near the bridges, is due to the decomposition of the organic matter so largely thrown into it from the sewers?—Yes.

98. Have you found water to absorb this gas from the air under any circumstances?—I have detected it in water placed within the influence of the emanations of a privy, from which, as is well known, large quantities of this gas are given off, especially in the hot weather of summer. It, therefore, becomes very probable that the water of cisterns placed near privies, or over closets, as they too frequently are, is sometimes contaminated by sulphuretted hydrogen.

99. Is not this gas highly prejudicial to animal life?—Yes, very much so, and in large quantities even fatal. There can be little doubt also, but that, in the quantity in which this gas is contained in Thames water, it exerts an injurious effect on health, whether it be directly introduced into the stomach in the water drank, or whether it be received into the lungs in the vapour of Thames water. At all times, but especially in hot weather, a large quantity of water rises by evaporation from the river; this is rapidly diffused throughout the atmosphere of the whole city, and in this way the gas in question reaches the lungs of every inhabitant. This consideration forms an additional reason why sewage should not be discharged into the Thames near London.

100. What is the effect of filtration upon the aeriform substances contained in water?—The general effect is to remove a certain portion of

the gases; there are, however, particular effects according to the filtering media employed, and the nature of the gases present. Dr. Arthur Hassall.

101. How do you account for the fact that water taken high up the Thames, before it is mixed with the filth resulting from extensive traffic on the river, and the sewage of large towns, is brisk and clear, while if obtained lower down it is flat and dead?—If obtained high up the river, its comparative freedom from organic and other impurities accounts for its clearness and much of its freshness; its briskness depends upon the amount of carbonic acid gas which it holds in solution; if procured low down the river, near London, its extensive admixture with, and contamination by, sewage, decomposing organic matters, and deleterious gases, sufficiently explains the dead and turbid character of the water.

102. Is a stagnant condition of water, or one of motion, favourable to aeration?—To this question I am scarcely able to reply very satisfactorily. I believe, however, that motion greatly promotes the aeration of the water. Thus, if we merely breathe upon the surface of a tumbler of distilled water, a much longer time will be required to impregnate the liquid with the carbonic acid gas contained in the breath than if we were to pass a current of respired air through it by means of a little glass tube. The motion of water agitated by wind or storms of rain, &c., is of a somewhat similar character, and is probably attended by increased aeration.

103. Upon what does the smell which impure water frequently possesses depend?—Generally upon the presence of vegetable and animal matter in a state of decomposition, and which, in that condition, gives rise to the formation of sulphuretted and phosphuretted hydrogen gases, both of which have a peculiarly offensive odour.

104. Have you been able to detect any unpleasant odour in the water of the Thames?—I have on several occasions detected in Thames water from the neighbourhood of the bridges a very decided smell of sulphuretted hydrogen; and in other instances the water has possessed a strong fæcal odour.

105. Have you noticed any unpleasant taste in water containing decomposing vegetable and animal matter?—I have; on several occasions.

106. From the river the water is often carried into a court or alley, and placed in a tank or tub, sometimes near the privy, when it quickly begins to smell disagreeably; the same is the result if it be kept in a room where persons are crowded together. To what is this attributable?—To the decomposition of the organic matter contained in the water, favoured by increased temperature, and to the direct absorption of sulphuretted hydrogen, ammonia, and vitiated air, the last especially, in a close room.

107. What are the effects of the respiration of animals and plants upon the composition of the atmosphere, and upon the aeration of the water?—The general effect of the respiration of animals which live on the earth is to occasion the deterioration of the air by its admixture with the carbonic acid, so largely present in the breath or expired air; while that of the respiration of terrestrial vegetables is precisely the reverse, they absorb the carbonic acid of the air, fix the carbon in their own tissues, and yield up the oxygen; thus the general effect of the

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respiration of plants is to counteract the tendency to atmospheric deterioration occasioned by the respiration of animals. Now the same law holds good with respect to the respiration of the animals and vegetables present in water, the tendency of the one is opposed by that of the other, and hence we find that in water, as well as on the earth, animal and vegetable productions are constantly associated and naturally dependent upon each other.

108. Have you made any experiments upon the subject of filtration? —I have, a considerable number.

109. Will you be good enough to state their nature?—I would observe that filtration is an operation which is carried on in nature on a large scale, and in a very effective manner; looking upon the surface of the earth, and reflecting upon what passes there, many instances of filtration present themselves to our notice; it is by filtration that the water which falls upon the surface of the earth in dew, showers of rain, or storms of hail or snow, makes its way into the soil which it vivifies; it is by filtration or percolation that this water passes from the soil into the cellular tissue of the plant which it pervades, imparting to it freshness and vigour; it is by this operation that the river as it flows along fertilizes the adjacent fields and pastures; the water of the pure well, or that which gushes from the spring, is filtered water, and man in his attempts at filtration does but imitate in a less effectual manner, and on a much smaller scale, a natural operation. Now filtration is of two kinds, mechanical and chemical; sometimes both are in action at the same time, and this is generally the case when water passes through soils. I first directed my attention to the mechanical properties of filters, experimenting with the following substances; namely, coarse and fine bibulous paper, wool, sand, vegetable charcoal, animal charcoal, mild and strong clays; it is proper to state, that the water employed as a test was green pond-water, the colour of which proceeds for the most part from the presence of myriads of *Infusoria*, of the genera *Microglena*, *Cryptoglena*, and especially *Euglena*.

110. Then your first experiments had reference to the removal, not of solid and inorganic particles, but of organic matter?—Yes, it was to this point that my inquiries were particularly directed, and in the first instance they were limited to living organic productions, as the *Infusoria*, &c. I will now proceed to state the results:—The water passed through *fine and coarse bibulous paper*, retained a very evident green tinge, deeper through the coarse than the fine paper, and examined through the microscope was found to swarm with *Infusoria*. Filtered through *sand*, it possessed an evident green colour, and contained multitudes of animalcules, some of large size. Passed through three different *patent filters*, it also came out retaining some colour and opacity, as well as numerous *Infusoria*. (In testing the powers of a filter, it is necessary that the first quart of water which passes should be rejected, as much of this, in general, does not consist of the water last placed in the filter, but of that retained in the filtering media from the previous filtration.) After filtration through *vegetable charcoal* the water entirely lost its green hue, but possessed a certain degree of opacity, and examined with the microscope the smaller animalculæ were to be detected in great numbers. Passed through *animal charcoal* the water came out bright and transparent, without colour or opacity, and no

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animalcules could be discovered in it. Through *loam* the water was still perceptibly green, and contained the animalcules in great abundance. Filtered through *mild* and *strong clay*, the water was nearly as clear and bright as through the animal charcoal, without trace of *Infusoria.* It is now to be observed that in all cases in which the *Infusoria* passed the filter, they were found, on examination with the microscope, to be in a living condition. In those cases in which they were entirely retained by the filter, the animalcules did not penetrate into its substance beyond the depth of an inch, or at most two inches. It may be objected to these experiments, that the green water employed was not fair test water, inasmuch as filters are not in general required to purify such water; this objection is more specious than real, for all water contaminated with *Infusoria*, contains some of the smaller kinds of animalcules, and the ova of all; these, therefore, are equally liable to pass the filter as those of the green pond-water, and that they do so is shown by the results of the filtration of Thames water given hereafter.

111. Are we to understand from these experiments that by filtration through clay and animal charcoal the *Infusoria* were entirely removed?—They were so far removed that none could be detected by means of the microscope; however, I took the precaution to preserve for the period of a fortnight some of the filtered water, and on examination at the expiration of that time I again discovered the same species of *Infusoria* as were present in the water previous to filtration; this shows that although the animalcules themselves were removed, yet that their ova were not entirely so.

112. Did it occur to you to filter Thames water as procured from the river, near the bridges?—It did; some Thames water was passed through one of Lipscombe and Co.'s filters. *Before filtration*, the water was dirty and opaque, containing much dead organic matter and grit, as well as numerous *Infusoria*, especially the Thames *Paramecium*, *Diatomaceæ*, and filaments of *Fungi*. It also furnished distinct evidences of the presence of sulphuretted hydrogen. *After filtration*, it came out clear and bright, without visible sediment or discoloration; examined with the microscope, nearly all the dead organic matter and grit was found to have been removed, and comparatively but few living productions were present: three or four *Paramecia*, *Oxytricæ*, and minute *Naviculæ*, with fragments of filiments of *Fungi*, and numerous ova and monads of small size. No sulphuretted hydrogen.

113. Were the animalcules in the green pond-water very small?—Yes, many of them exceedingly minute; in fact the smallest known.

114. It may be safely assumed, I suppose, that those substances which most effectually arrest living organic matter, will intercept in an equally efficient manner dead organic particles?—Undoubtedly; I would now observe, that I put the mechanical powers of the different filtering media enumerated above to a still severer test than that of the green pond-water, thus: I passed through each a portion of fresh milk; those who are acquainted with the microscopic constitution of this fluid, will know how admirably it is fitted to serve as a test liquid for filters; the butter is contained in milk in the form of globules of variable sizes, but some of which are exceedingly minute, and it is to the presence of

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these that milk owes its opacity and colour: except from the animal charcoal and the mild clay (the strong was not employed), the milk as it escaped was observed to retain much of its colour and opacity, and this was the case even with that which came away from the vegetable charcoal and the patent filters; that, however, which flowed from the animal charcoal and mild clay, was nearly but not quite as transparent as pure water, and on microscopic examination the globules of butter could not be detected; these were all retained on the surface of the filters, where they formed a thick stratum of cream.

115. Much has been said upon the subject of filters not retaining the fluid or soluble organic matters present in some liquids and in impure waters; have you directed your attention to this point, and can you state from observation or experiment whether filters do or do not intercept such fluid organic substances?—I have made many experiments in order to determine this point; I first passed some recent human urine through vegetable and animal charcoal, loam, and mild clay; passed through the vegetable charcoal, the urine still possessed some colour and a faint urinous smell; through loam the colour was deeper and the smell stronger, while through animal charcoal and clay the urine was as clear and as free from colour or smell as the purest water; tested for the peculiar colouring matter of the urine, this was abundant in the urine from the loam and vegetable charcoal, with but faint indications only of its presence in the animal charcoal and clay, least of all in the former; tested for urea, (an effete animal substance,) this was found to be present in abundance in all the examples of urine; the crystalline substance, formed with nitric acid, on the evaporation of a given quantity of the urine, being beautifully clear and colourless in that from the animal charcoal; chlorides and sulphates were all present in each case. I next tested the serum of milk filtered through animal charcoal and mild clay, and here I found the caseine or cheese in abundance; it is thus evident that fluid animal substances are not entirely arrested by even the best filters. I will now show that fluid vegetable substances are likewise not intercepted, or rather that some filters themselves yield to the liquid filtered fluid vegetable matter; the first portions of water passed through loam are usually beautifully clear and colourless, but after a time, and as soon as the soil becomes thoroughly saturated, the water is often turbid, and of a deep brown colour. Now, if lime-water be added, even to the clear and colourless water, in a few minutes a change in the liquid will be observed; it will become of a bright brown, almost gold coloured, and finally it will deposit a brown sediment, which is the lime in combination with the vegetable substance.

116. Have you instituted any experiments with the view of determining the effect of filtration upon the aeration of water?—I have made some observations in order to ascertain the power possessed by certain filters to absorb and remove sulphuretted hydrogen and carbonic acid from water. Paper, sand, and wool, being for the most part mechanical in their action, it was not necessary to experiment with them. Sewer-water, holding in solution a large quantity of sulphuretted hydrogen and of organic matter, emitting an odour in a high degree offensive, was passed through the following substances:—

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Vegetable Charcoal.—From this it came out free from smell, and colourless, yet evidently somewhat opaque; tested for sulphuretted hydrogen, this gas was not found.

Animal Charcoal.—Through this the water escaped clear and brilliant, without the slightest opacity, and showing no traces, on the application of tests, of the presence of sulphuretted hydrogen.

Patent Filters.—Passed through these, the water passed with a slight tint of colour and opacity only, but furnished evident traces of the presence of the gas in question.

Loam.—From this the water came out in scarcely so pure a condition as from the filters, and also contained sulphuretted hydrogen.

Mild and Strong Clays.—Through these the water passed as clear and transparent as through the charcoal, but yet was found to furnish distinct evidences of the presence of the gas. The sewer water, tested for sulphuretted hydrogen before being passed through a filter, gave with lead a dark brown precipitate; while, after having been filtered through the patent filters, loam, and clay, the colour of the precipitate was of a light brown. It is, therefore, evident that all the above filtering media are, to a greater or less extent, chemical; and that, while some of them absorb the whole of the sulphuretted hydrogen, others retain only a portion of it. Most of the patent filters are made with a certain amount of charcoal, and hence their chemical properties. Now, although the water employed in these experiments was sewer water, yet the same proportional effects would follow the use of any water containing sulphuretted hydrogen. Again, Thames water, known to contain sulphuretted hydrogen, was passed through the same media, and when tested for the gas it was found in all the filtered waters, except those which had come through the animal and vegetable charcoal. When acetate of lead was added to the water filtered through loam, a precipitate was obtained somewhat similar to that noticed on the addition of lime water, and indicative of the presence of organic matter.

117. What experiments did you make with the view of ascertaining the effects of filtration upon the amount of carbonic acid present in water?—Water highly saturated with carbonic acid was passed through the same media as the sulphuretted hydrogen. After filtration through animal and vegetable charcoal, a trace only of carbonic acid was to be discovered; the water filtered through loam and mild clay contained the gas abundantly, but yet in much less quantity than previous to filtration. After passing through the patent filters the water gave distinct evidences of the presence of carbonic acid, but in less amount apparently than that from the loam and clay.

118. Are you acquainted with the effects of filtration upon the oxygen of the water?—I am not; it is most probable, however, that a portion of the oxygen is removed at the same time with the carbonic acid of the water.

119. Did it suggest itself to you to try the effect of filtration upon the amount of carbonic acid present in any water in common use, as Thames water?—I passed Thames water through animal and vegetable charcoal, a patent filter, loam, and mild clay. Much of the gas was abstracted by the animal and vegetable charcoal and the patent filter, but nearly the whole of it, as well as the carbonates of the water, were removed by the loam and mild clay, and by the loam in a more com-

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plete manner than the clay; the same discoloration was to be observed in the water from the loam, to which lime was added, as previously noticed and remarked upon.

120. Have you made any observations on the power of soils, and other substances, in removing salts from water?—I have not extended my observations to this branch of inquiry; I may be permitted to observe, however, that the majority of the results of filtration through soils are determined by and dependent upon the general laws of chemical affinities, rather than upon any peculiar and absolute powers dwelling in particular kinds of soil; thus the results of filtration through soils are generally to be explained by the chemical constitution of the soils themselves. Water passed through animal charcoal will bring away with it some of the phosphate of lime present to the amount of 10 per cent. in that substance.

121. Will you now, as briefly as possible, enumerate the results which appear to rest upon the various experiments on filtration which you have detailed?—From the results of these experiments the following conclusions may be safely deduced:—1st. That bibulous paper, sand, wool, and loam, are bad mechanical filters; 2nd. That vegetable charcoal is by no means a perfect one; 3rd. That the mechanical powers of patent filters are in general but limited; 4th. That animal charcoal, mild and strong clay, are nearly perfect as respects their power of mechanically retaining the solid matter, dead and living, found in even the worst descriptions of water; 5th. That inasmuch as the animalcules pass through some media in a living state, that these, including loam, do not exert any chemical effect upon living organic particles; 6th. That soluble organic matters, either animal or vegetable, are not in general removed even by the more perfect methods of filtration; 7th. That some soils, as the loams which contain a large amount of dead and decaying organic matter, principally vegetable, give up to water fluid organic substances; 8th. That the effect of filtration on the aeration of water is to lessen the quantity of aeriform substances contained in it; 9th. That for the removal of sulphuretted hydrogen, charcoals, especially the animal, are best; 10th. That animal and vegetable charcoal, loam, and mild clay, all remove the greater part of the carbonic acid present in water, the two latter abstracting likewise its carbonates.

122. Did you notice any great difference in the relative speeds with which the several fluids passed the filters?—I did, very great differences; the worst mechanical filters are in general the quickest filters, while the best are the slowest in their action; of the more perfect filters, animal charcoal is the quickest.

123. How are these differences to be explained?—By reference to the size of the integral particles composing the various filtering media; thus the microscope clearly shows that the constituent particles of the best filters are very small in size, while those of the worst are larger. It is worthy of observation, however, that the absorbing power of substances for gases is to a great extent independent of size; thus coarsely powdered vegetable charcoal will take up gases equally well, if not better, than when reduced to a very fine state of division.

124. The conclusion therefore appears inevitable, from the results of your numerous observations on filtration, that although the grosser

impurities of water may be removed by this process effectually carried out, yet water highly contaminated with organic matters, especially fluid, cannot be wholly purified by filtration?—Exactly so; and I would observe that there is great reason to believe that the fluid impurities of Thames water within some miles of the metropolis are very great in amount and variety.

125. Would you now describe the nature of the apparatus employed in your experiments?—The different filtering media were placed in glass cylinders of about two inches in diameter, each holding one pound and a quarter of material, and which formed a stratum of from nine to ten inches in thickness; increasing the thickness of the strata, which might be done to any extent, would of course modify the results obtained considerably.

126. Then we may state it as a conclusion that the microscope does display differences in water which chemistry cannot detect?—The microscope undoubtedly develops facts which chemistry could never arrive at, and which it is not the province of that science to deal with.

127. Especially as regards the salubrity of the water, for while chemistry discovers what makes water hard, or its saline and mineral constituents, it fails to show the nature and varieties of the organic matters contained in it, and upon which the deleterious qualities of water in general depend?—Chemistry does not inform us of the species and modes of life of the various creatures found in river and many other waters.

128. Is there not a great amount of animal life in water which can hardly be said to be inconsistent with the general good health of those who drink it?—I should say, decidedly not; all living matter contained in water used for drink, since it is in no way necessary to it, and is not present in the purer waters, is to be regarded as so much contamination and impurity, is therefore more or less injurious, and is consequently to be avoided. There is yet another view to be taken of the presence of these creatures in water, viz., that where not injurious themselves, they are yet to be regarded as tests of the impurity of the water in which they are found.

129. Then you think that the importance of the presence of these species is less from their actual consumption than from their being indications of the presence of animal and vegetable matter in a state of decomposition, and on which they feed?—Yes; such is, no doubt, the correct view to take of the presence of the majority of living productions found in water; it is doubtful, however, whether some of them may at all times be consumed with impunity.

130. What are the observed effects of the consumption of the various forms of animal and vegetable life present in water on health?—The fact of the existence in large quantities of living productions belonging to several distinct divisions of the organic world, and for the most part entirely invisible to the common eye in the waters in general use, was not, I believe, generally known until announced by myself in the pages of "The Lancet" some weeks since; it is, therefore, scarcely to be expected that there should as yet have been made many observations tending to show the effects of their consumption upon health; nevertheless, we are not altogether without sufficient data upon which to found an opinion; thus the organization and mode of

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life of many of these productions, as the *entomostraceæ*, most of the *infusoria* and *algæ*, are such as clearly to unfit them for any prolonged existence in the human stomach and intestines, and there is no question but that when introduced therein they speedily die, the digestible portions of them being assimilated; but whether this is the case with the *fungi*, the *annelidæ*, and certain *infusoria* and *algæ*, admits of considerable doubt. It is a well ascertained fact that the *fungi* have the power of attacking and even proving fatal to many vegetable and the lower forms of animal life. I may here refer to certain experiments which I made some years since to test the aggressive and parasitic powers of *fungi*. Many fruits, such as apples, pears, and peaches, and several vegetables, as the lettuce, vegetable-marrow, potato-haulm, &c., were inoculated with the sporules of *fungi*; the result of this was that they all became speedily diseased, and in a few days many of them entirely disintegrated and destroyed. It is to be observed that these experiments were made on healthy and growing fruits and vegetables; the former were still on the trees, and the latter rooted in the earth. In the softer fruits, as the peach and some kinds of apples and pears, the effects of the inoculation became visible in less than 24 hours, a dark spot, like that of mortification, first appearing, and this gradually extending in all directions until the fruit became completely disorganized. There are now also many recorded cases in which *fungi* have attacked the living animal organism, including even man himself; the disease, muscardine, which occurs in the silk-worm and many other animals of the same class, as well as the peculiar softening which the tails of fish confined in glass globes frequently undergo, is attributable to the growth within the tissue of the animal of ramifying filaments of *fungi*. Again, *fungi* have been noticed growing on ulcerated surfaces in the human intestines in cases of fever; they have likewise been observed in certain affections of the skin, and in discharges from the stomach, bowels, bladder, and vagina.

With respect to *annelidæ*, it is commonly known that several species of worms live in the human intestines, and even grow and multiply there, greatly to the detriment of health, and it is difficult to avoid the conclusion that they are really introduced from without, either in the water, or through the medium of the food.

Animalcules widely differing from each other have also been observed to occur in the human organism in connexion with certain diseases. Thus Donnè has figured and described a vibrio, under the name of the venereal vibrio; the same observer has likewise noticed in vaginal discharges *infusoria*, which he has named *trichomonades*, and which, as well as the vibrio, are figured in my work "On the Microscopic Anatomy of the Human Body in Health and Disease." Other animal productions have been noticed in the humours of the eye, in the muscular tissue, in the gall-bladder, &c.

The only instance of an *algæ* being found in connexion with the human subject is that recorded by Dr. Arthur Farre: it was observed in a case of vomiting, and has been named *Sarcina ventriculi*. It is now to be observed that the greater part of the living productions noticed in relation with man have had their seat on the surface of the body, in the stomach, intestines, gall-bladder, or in the urinary passages, uterus and vagina; that is, almost invariably in positions accessible to

the air, an observation leading to the conclusion that they found their way into the frame from without. The general immunity of the lungs from parasitic developments, either vegetable or animal, is remarkable. Dr. Arthur Hassall.

131. The *diatomaceæ* are, I believe, furnished with skeletons of silex; what becomes of them when introduced into the stomach, and is it probable that they could give rise to results injurious to health?—The vitality of the *diatomaceæ* is most probably destroyed when introduced into the system; they pass, however, in an entire state, and when consumed in any quantity, it is quite possible that they might give rise to irritation, in consequence of their unyielding nature and of the elongated and needle-like character of most of the species, the extremities of the frustules frequently being finer and sharper than the points of needles.

132. You find some animalculæ show the presence of decomposing animal or vegetable matter, but I suppose you have not had evidence of persons going from one kind of water to another, and finding variations of health in consequence?—I have no original observations to offer on this point. I would remark, however, that except in times of epidemics we ought not to look for any sudden or violent effects from the use of water impregnated with living or decomposing vegetable and animal matters; these effects, like those of vitiated air, are slow and insidious, but not the less important and the less to be dreaded.

Hector Gavin, M.D., F.R.C.S. Ed., Lecturer on Forensic Medicine, Charing Cross Hospital, examined.

Have you not paid considerable attention to the sanitary condition of your district?—I am intimately acquainted with the sanitary condition of the surrounding districts. Dr. Hector Gavin.

And you have also been engaged as Medical Inspector in aid of the General Board of Health?—Yes.

Have you observed the water supply in your neighbourhood?—I have, very particularly.

What are the districts, and by what companies are they supplied?—Hackney, Bethnal-green, and Shoreditch; they are supplied by the New River and East of London Water Companies, and on the intermittent system.

What proportion of the people you visited during the house-to-house visitation were supplied by stand-pipes?—In Hackney about half the houses are supplied by stand-pipes; in Bethnal-green, with very few exceptions, the dwellings of the poor are supplied with water by means of stand-pipes; in Shoreditch a larger number of houses have water laid on, but still the number of dwellings supplied by stand-pipes is very considerable. In a few instances some squares or rows of houses, as Thorold-square, Bethnal-green-road; the Crescent, Hackney-road; the Crescent, Union-street, Kingsland-road, have sunk reservoirs communicating with the main, which by means of a pump supply water constantly to the inhabitants. With these exceptions all poorer and middle-class dwellings in Hackney, Bethnal-green, and Shoreditch are supplied

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as I have mentioned. The poor preserve the water either in 1° butts—cisterns are almost unknown (I only met with two attached to the dwellings of the poor and middle classes in Bethnal-green, the one was a large covered butt, the other an open wooden cistern containing the remains of cooked fish), or 2° small tubs, or earthenware jugs, pans, or sometimes in small crockery-ware bowls, and sometimes soup-plates. Water preserved in such tubs or pans is nearly always taken in-doors. Such vessels are never covered. Even where there are small butts, the water is still preserved in-doors in small open vessels; when there are tubs, the tubs are very frequently stowed away below the beds. In one instance a child fell into one of these tubs, which projected from below the bed, and was drowned.

Then it is incident to this plan for having water from stand-sipes that the people keep the water in their rooms?—Yes; even where there are butts, they are so small that the people attempt to increase their store of water by preserving some in open vessels in their rooms; in all other cases it is the nearly invariable practice of the poor to preserve their water for drinking and cooking *in their rooms.*

What is the effect of the retention of water in close atmospheres?—In some places I have found the water used for drinking and cooking almost putrid, even where it had stood for a short time only; in nearly every place, whenever the water has been retained for a day, it has become offensive to the taste. When the water is preserved outside of the house, it is always retained in open vessels; the butt is generally situate close to the privy, sometimes under the same roof; the water is therefore always exposed to the impurities floating in and liable to be deposited from the atmosphere, and always liable to be contaminated by the absorption of foul and malarious air arising from the privies and the back yards saturated with the débris of decomposing matters. When water is taken into the close, heated, and offensive rooms of the poor, it rapidly absorbs the offensive gases, &c., and becomes tainted; and when the water has been preserved some time in butts or tubs outside, exposed to the fœtid atmosphere of a privy, it taints still more rapidly. It is almost impossible, on calling for a tumbler of water in the houses of the poor, to find it free from a mawkish taste. As an example of the mode of supply by butts, I may refer to Beckford-row, Bethnal-green. The butt, 21 inches in diameter by 12 inches deep, is under the same shed as the privy. It supplies water to Beckford-row and Alfred-row; the former consists of 16 2-roomed houses, each having a separate family. The latter row is the southern half of Beckford-row; the water supply to the occupants of these 48 rooms consists thus of about as much as would subserve to the wants of one individual. When it is considered that the supply is intermittent and thrice weekly, the deficiency in the storage for water under the intermittent system may be estimated. A particularly objectionable manner of storing water consists in retaining it in small butts or tubs, wholly or half sunk in the ground. This mode prevents the butts or tubs from being cleansed, and the sediment which collects from being removed. Water retained in such receptacles is of a mawkish, earthy taste. This mode of preserving water is common to several of the places called "gardens" in Bethnal-green. It follows, from the general want of external means of storing water, and from the

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small size of the existing receptacles, that the poor are compelled to preserve their water in small vessels, and, as a rule, in their own rooms.

What was the size of the butts?—Ridiculously small; the tubs are generally shallow vessels, which expose the whole surface of the water to the filthy atmosphere, and they are generally placed, as I have observed, close to some privy or dungheap. As an example of the mode of supply by butts, I may refer to the small barrel for the storage of water for the inhabitants of Beckford-row.

Do you concur that if the system of distribution were such that the water might be laid on in each landing-place, already filtered, a great alteration would result in the habits of the people?—I know nothing that would more immediately effect a great change than an ample supply of water. The habits of the people are created by circumstances and by education. Nothing struck me more forcibly than the arduous efforts of the poor in the districts I have mentioned to be cleanly, and the readiness with which, on a supply of water being laid on, they have availed themselves of the means of cleansing it afforded. In the erections of later date in towns and cities, where a constant supply of water has been laid on to each house, this mode of supply in a very short time led to a marked difference between the habits of the people who were, and those who were not, thus supplied with water; and I have observed similar results during the late visitation, when supplies of water were in some instances more liberally accorded. I have found the poor busily engaged, when it was on, in scouring and washing down their footpaths and yards, and congratulating themselves on the opportunity which this extraordinary supply afforded them of being clean "*for once.*" I have invariably found that where there were larger supplies of water, the people were more cleanly in their persons and dwellings. Under the present system cleanliness, either of person or dwelling, is perfectly impossible. This uncleanliness results not only from the impracticability of storing water sufficient for their wants, it arises in numerous instances from the water from the stand-pipes, on each occasion of its "coming on," flooding the yards, courts, paths, &c., and keeping the place constantly miry. Besides the mere uncleanliness arising from this mode of supply, the system is most injurious in another way:—When the water is on, a partial flooding takes place, in consequence of the want, or the insufficient state, of the drainage. The water sinks into the ground, renders the houses damp, and the inhabitants diseased; by the partial flooding of the yards, the refuse with which at the present time they are almost invariably covered becomes moistened, and during the process of drying in the sun the moisture readily carries up the destructive products of the decomposition going on. I am satisfied from my own observation that much disease is produced in this way. The quantity of water thus run through the drains by overflow is just sufficient in such places to stir up the putrescent mud in the half-choked drains, without ever effectually cleansing them. By the proposed system of distribution much toil and labour would be saved to the poor, especially in close and lofty dwellings, such as in the cholera districts of Bethnal-green, Shoreditch, Spitalfields, Whitechapel. Where there is much labour entailed on the poor in carrying water up and down stairs, cleanliness is much neglected, and the upper rooms generally show more neglect and uncleanness than the lower. In Whitecross-place, for

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instance, referred to in my Report on Shoreditch, there are five stories to some of the houses, each room containing a family. The deaths from cholera took place in the very top story, which showed much more uncleanness than the lower rooms. In these upper rooms the inhabitants used the water over and over again, until it became very offensive, and "past using." The drinking-water is stated by the visitor to have been "horribly offensive." The poor man, a shoemaker, and his wife, stated a few days before their deaths that they had not tasted a drop of water fit to drink since they had been in that house. Besides the results just referred to, the foulness of the water, acquired by exposure to a close and offensive atmosphere, renders it particularly odious to the poor as a common beverage. The water, often very much loaded with sedimentary matter, and subsequently rendered offensive, becomes unpalatable to the poor, who have no means of filtration; they therefore have recourse to beer, which has become a common beverage of the people of London, as much, if not more, from the impurity of the drinking water supplied to them than from any other cause. I have, in making inquiries among the poor, constantly had this reply,—"We cannot drink the water, Sir, it is so nasty; it makes me ill." This common observation among the poor is borne out by the evidence of strangers, who generally complain of slight diarrhœa after drinking the London water for a few days. I have every reason to believe, that were a pure and wholesome water supplied to the poor of London, it would be found that in a short time intemperance and beer-drinking would become much less common. This evidence is the result of my inquiries among the poor themselves, continued for several years.

During your experience of the recent epidemic could you trace the effects of using foul water?—The connexion between foul drinking-water and cholera was established by irrefragable evidence. The cases where the connexion was most clear were where the parties had been recently drinking water taken from pumps near to, and contaminated by the matter of cesspools; but wherever the water was contaminated so as to be nauseous, diarrhœa was invariably present, and affected every person in the habit of drinking such water. I am not aware of any valid exceptions to this law. The most aggravated instance of foul water developing cholera was where a thirsty navigator drank of the Hackney-brook (a common sewer), and was almost immediately attacked with cholera, and subsequently speedily died. The cases next most marked were those of the 11 persons, out of 22 in number, whom I have already recorded as having perished in a certain square consisting only of a few houses, where the water was contaminated with cesspool matter. A similar story I have related with reference to the first outbreak of cholera at Fulham. In Hackney I have shown how that, out of 63 inhabitants of one locality who drank of water contaminated with cesspool matter, every one had had, or then had, more or less diarrhœa, and that to avoid its excessive filthiness the whole of the inhabitants of that row were compelled to drink and use for domestic purposes the water which ran down the kennel. These are the more marked instances, but the cases where foul water led to the development of cholera were so numerous, that all the visitors under my superintendence united in their testimony as to the influence of such water in the development of the disease. I have traced in many instances the unsuspected cause of the

development of cholera in the state of the drinking-water. When it is recollected that the water of the poor is nearly always exposed to the noxious gases and agencies which arise from privies, and the slow decomposition of the refuse in their yards, and also from those in their close, offensive, and impure dwellings, it will at once be understood that such water produced much and severe diarrhœa during the period of cholera. Dr. Hector Gavin.

Is it within your observation that a considerable waste of water results from the present system of distribution?—Yes, a very great waste; for, as a general observation, a small proportion of the water is caught by the receptacles used in the houses of the poor, and of course the rest runs away during the whole period for which the water is let on. I should estimate the general waste among the dwellings where one stand-pipe supplies two or three houses at many thousands per cent. Where one stand-pipe supplies a whole court much less runs to waste; still, in no instance such as these, that I am aware of, can the waste be calculated at less than three-fifths of the supply. It seldom happens that there is any stop-cock to the stand-pipe, and as it is nobody's business to prevent the waste, and as the poor are sure that in a short time the run will cease, they take no heed, and permit the waste-water too often to saturate their yards, and become a source of disease. If the water were on the system of a constant supply, they would be compelled, for their own comfort to check the flow of water.

Robert Bowie, Esq., Surgeon, examined.

1. You are a surgeon I believe?—Yes. Mr. Bowie.

2. And have attended especially to the consideration of asylums for affording nightly shelter to the houseless poor, to baths, washhouses, and model lodging-houses, and to other appliances for the improvement of the sanitary condition of the labouring population of the metropolis?—I have.

3. You have also acted in aid of the General Board of Health?—Yes.

4. Were you not directed to make special inquiries on the part of the Metropolitan Sanitary Commission as to the supply of water in the city of London? Will you explain in what state you found it?—In general very scanty, and sometimes altogether wanting. The water often thick, muddy, discoloured, putrid, and unfit for drinking or culinary purposes. I would instance as proofs of this statement, out of a host of others, the houses in Fireball-court, Three Pigeon-court, Cock-and-Hoop-court, Seven-Step-alley, Houndsditch; Crown-court, Seething-lane; Barking-churchyard; Rose-lane, Tower-street; Pewterers'-buildings, Cannon-street; Printing-house-square, Coleman-street; Saddler's-place, London-wall; Ivy-lane, Newgate-street; Mac's-place, Greystoke place, Fetter-lane: all in the city, where the inhabitants thus express themselves, that "The time the water was on was too short, the fatigue of carrying it up stairs very oppressive, and much time lost in procuring it." "There was no water laid on." "Water was got where they could, by begging, borrowing, and from the neighbouring pumps." "They have been without water for eight years, and often more in need of it than victuals." "They have been without

Mr. Bowie. water for nine years." "The water is dipped with pails, and is often very dirty." "The water, instead of being clear and fit to drink, often looks quite yellow." "The water in the cistern is only fit to rinse a pail or cleanse the privy, as every impurity gets into it. It has even been used for drowning kittens. Two open tubs stand behind the door of the kitchen as water-butts, and have only been cleansed out once in the nine years." "The water (supplied from a pump) is shockingly bad, tasting as if they were drinking something putrified, and often containing live worms more than an inch long, supposed to be from the burying-ground at the back of the house." In addition to this, a gully-hole is in close connexion with the pump by which foul water may find its way into the well. There is an evil of considerable magnitude likely to result from the practice of having public pumps or stand-cocks to supply a neighbourhood with water. It is that, as children and females have to go and wait their turn, they may come in contact with persons of the worst character, hear very bad language, have their sense of delicacy impaired, and at last become regardless of decency.

5. Have you observed any effect which you think was due to the position of cisterns and butts in houses?—Yes, in badly ventilated cellars, for instance, where water was kept near the privy or cesspool, I found that the water had become very unpleasant.

I am of opinion that the common practice of placing water-cisterns immediately above water-closets (unless for the sole use of these closets) is not only injudicious but abominable, seeing that the pipe conveying the water must often be charged with most offensive gases, which in passing through the water in the cistern are likely to communicate a portion of their odour.

In consequence of my attention having been drawn to this point, I caused the valve mentioned in my evidence before the Sanitary Commission to be made fast in the cistern of the Eastern Asylum, instead of allowing the water to flow into the closet, until a separate vessel has been provided. It was the sound of the air rushing into the cistern when the valve was raised that first excited my suspicions.

6. How did you find water in rooms where they were crowded?—Generally very impure and offensive.

7. Then, according to your experience, water, which when procured from its source was good, became bad before it was consumed?—Certainly: I have seen it with a film of dust upon its surface, and smelling shockingly, when it had been kept in the house for some time in pails, tubs, pans, jars, and pitchers;—vessels themselves scarcely ever sufficiently cleansed, owing to the difficulty and labour of procuring a proper supply of water.

8. Have you had experience of a population using soft water?—Yes, in several parts of Scotland.

9. What is its advantage in culinary purposes?—I have frequently heard persons who had been accustomed to use soft water remark that hard water was not so well adapted for making tea or cooking vegetables.

10. Is not the New River supply complained of as hard?—Very often, and with great justice. It curdles soap quite as much as it dissolves it.

Mr. Bowie.

11. What is the difference of the water in making tea?—Soft water gives a much stronger extract: where the water is very hard a greater quantity of tea is required. People often think the tea itself is not strong; and I have seen some ladies put a lump of sugar into the teapot, and others a little soda, for the sake of extracting the strength of the tea, where the water was hard.

12. If the water were agreeable in quality, and so distributed as to be regularly supplied and easily attainable, do you not think that a large portion of the labouring classes would prefer drinking water to gin or beer?—I am certain of it, for I have often heard persons declare that they were so distressed for water as to be obliged to resort to beer or spirits.

In Merthyr Tydfil, Pen y darran, and Dowlais, in South Wales, the scantiness and badness of the water were again and again assigned to me as the chief causes of the excessive drunkenness so general in these places.

13. Do you believe that if soft water could be procured it would be much better for bathing purposes also?—There cannot be a doubt of it: hard water, as I have already said, curdles soap, and renders it to a certain extent unserviceable. I consider that pure soft water, while it would be more agreeable to the skin, would be more effective without soap than hard water with it.

14. Will you compare the water used in the baths at the east end of London with the Artesian well water at St. Martin's baths?—The following extract from Mr. Lewis Thompson's Report on the water used at Goulston-square will perhaps suffice. "The specific gravity of the water of East London is 1·004. It is turbid, and contains a yellow tinge, even after filtration. When heated highly, atmospheric air and carbonic acid gas are disengaged from it, and, by boiling, a precipitate is produced. An imperial gallon contains the following solid ingredients: Carbonate of lime, 18·55; sulphate of lime, 5·25; muriate of lime, 7·85; organic matter, 4·20; with distinct traces of common salt, sulphate of soda, and oxide of iron. The water is very bad after heavy rains.

15. Do you find that hard water has an effect upon the pipes in which it is conveyed?—It has; at Goulston-square baths the pipes became so encrusted, that sometimes only four or six baths were available for the whole establishment. This was owing, however, in some degree, to the high temperature necessary to force the hot water from the boilers into the baths, and the defective state of parts of the new machinery; for at Glasshouse-yard free baths and washhouse, using the same kind of water, no such accident has ever happened. The water supply to both establishments is from the East London Water Company. I saw a very large pipe at the City Club, Broad-street, completely blocked up with similar incrustations. It had been used for circulating water at a very high temperature for warming the building. The supply was from the New River.

16. The water at the East End is delivered unfiltered, is it not?—Yes; and after rain is very much discoloured, thick, muddy, and contains a good deal of vegetable fibre and other organic matters. The first year of the potato disease I imagined, as did others to whom

Mr. Bowie. I mentioned the circumstance, that the water both from the New River and the East London Works had the peculiar smell belonging to that affection, especially after heavy rains or land-floods.

The following statement was made to me by a respectable individual well acquainted with the locality:—

The water from the Thames passes up the river Lea at the top of spring tides, rises above the level of the reservoirs or tanks of the East London Water-works, at times filling them. The water of the Lea, near Bow, is exceedingly foul. Numerous dye-works, breweries, distilleries, chemical works, foul black marsh ditches, full of everything horrible, and common sewers of large diameter, empty themselves there. There is also at times a supply of highly offensive and deleterious matters carried into it from the chemical and copper works on Bow Common, a place famed for its intolerable stench, and never visited but on business or from necessity.

I have satisfied myself that this is no overdrawn picture, and lament that fellow-beings in this age of civilisation should be so dirty in their tastes and habits as to remain contented with water so contaminated, when, by proper filtration, the evil might be greatly lessened.

At the East End of London, in addition to the impurity of the water, the supply is far too scanty, and in innumerable instances wanting altogether. In corroboration of this I offer a few extracts from evidence in my possession:—

Sun-court, East Smithfield.—"To supply about a dozen houses the water is on for half an hour daily." "Sometimes not at all." "Not half enough for the people in the court." "The family, seven in number, use 5 or 6 pails daily (10 or 12 gallons) when it can be got." "If 20 gallons were used it would be better, as there is only one privy in the court, and it is so dirty no one can go into it." "The water is seldom clear, sometimes very muddy."

Cooper's-row, East Smithfield, contains about eleven houses; five of which are supplied with water from a stand-cock, and four have no right to water at all. As might have been expected, in the latter houses the occupants are miserably dirty, wretched, loathsome, and generally depraved.

Cooper's-court, Blue-Anchor-yard, contains fourteen houses, all densely inhabited. In this court cholera prevailed to a most alarming extent. The water is only on for an hour daily. The tap is not an inch, it is only about half an inch, in diameter, being what is termed throttled near its orifice, presenting, therefore, a most deceptive appearance to a superficial or mere outside examiner. Averaging the population of this court to be 3 to each room, as there are 3 rooms in each house, the total will be 246, supplied from a ½-inch tap, for an hour, or say two hours, daily, not including Sunday, the water running a part of the time so slowly as to take a quarter of an hour to fill a two-gallon pail. But, besides the inmates of these houses, there are numerous applicants from Blue-Anchor-yard, who, like those of Cooper's-row, have to "beg or borrow."

All of those whom I saw or conversed with there complained bitterly of the want of water.

I may say, without fear of contradiction, that from Rosemary-lane,

and its continuation eastward, Cable-street, to East Smithfield and Ratcliffe-highway, on the south the supply of water is exceedingly defective, and the water itself very often impure. Mr. Bowie.

17. Does it come within your observation that in a period of epidemics the quality of the water increases the danger of its use if bad?—During the raging of the cholera I met with many cases where it was asserted that the badness of the water was the cause of the attack; and I have no doubt that it greatly tended to increase the liability to disease.

It is well known that cholera raged with frightful and destructive violence in Merthyr Tydfil, Pen y darran, Dowlais, and other mining towns and villages in South Wales; and in all of these places I heard the opinion expressed by many of the population that it was something in the water. The supply was wretchedly defective, and the water very impure. I may also refer to my report on Bermondsey; where, speaking of Jacob's Island, I mention that, "in this island may be seen at any time of the day, women dipping water with pails, attached by ropes to the backs of houses, from a foul fœtid ditch, its banks coated with a compound of mud and filth, and strewed with offal and carrion, the water to be used for every purpose, culinary ones not excepted; although close to the place whence it is drawn, filth and refuse of various kinds are plentifully showered into it, from the wooden conveniences of the wooden houses overhanging its current, or rather slow and sluggish stream; their posts or supporters rotten, decayed, and, in many instances, broken; and so little regard is paid to decency that women may be seen entering and leaving these projecting conveniences, and the filth dropping into the water, by any passer by. I was also informed, that during summer, crowds of boys are to be seen bathing in the putrid ditches, where they must come in contact with abominations highly injurious.

18. Was much of this supply obtained from the ditches in the neighbourhood?—Yes; some water was obtained from the Vauxhall Company's supply, but it was very limited: most of the houses were supplied from these ditches and mill-streams.

19. You say this bad water was from the ditches, not from the Company's supply?—Yes.

20. It is stated in evidence, both by the Engineer of the Vauxhall Company, and corroborated by their evidence, that about 190 or 200 gallons of water are pumped into this district per diem for each house which has a supply, and that about two-thirds or three-fourths of that quantity overflow from the butts and are wasted, and that in this particular district there is an amount of annual waste of water which equals, if it do not exceed, the whole quantity of annual rainfall in that district?—I have no doubt of it.

21. What is the average size of butts in that district?—About 60 gallons on an average.

22. Then you do not believe that poor persons use 20 gallons a-day?—Certainly not; they do not use 6 gallons oftentimes for a whole family, and frequently much less. If, however, they had it plentifully supplied them, without the trouble of carrying it up stairs, they would certainly use much more. Now they are so careful of the water, that it is often used first to wash one kind of clothes, afterwards

Mr. Bowie. another; and even then used a third time for some other purpose, until the effluvia become most offensive and sickening, communicating an odour to the clothes and persons of the inhabitants, rendering them exceedingly disagreeable.

23. Is there not here a great waste of human labour, considering that it was stated by the secretary to one of the London companies, in evidence before the Health of Towns Commission, that 80,0)0 gallons of water may be lifted by a Cornish engine 100 feet high at the cost of one shilling?—Yes; and it is likely to deteriorate materially the health of the population. As water might at very little expense be laid on in every landing-place, it ought to be done; for in poor neighbourhoods distinct families generally live on every floor. Now they often have to go down to the very cellar, or to a little back yard close to the privy, if they are fortunate enough to have the water supplied on the premises.

24. With reference to Jacob's Island and the district in Bermondsey which was ravaged by cholera, it is stated in evidence that, within 4 months from the time when the works might be commenced, all the cesspools might be abolished; that soil-pan apparatus might be laid down; that a system of complete house-drainage might be established; that permeable drainage might be laid down, which would carry away all the damp: and that all this might be done at a permanent charge, exclusive of the cost of water, of not exceeding 2*d.* per week per house. Supposing that were practicable and could be done in 6 months, what is your opinion with regard to any impending epidemic?—It would have a most happy effect, and produce a great result towards diminishing the violence of such an epidemic, or preventing its visit altogether. Wherever I have visited I have found that the attacks of epidemics are most infrequent where the most attention is paid to drainage, and where drainage has been most neglected the attacks are most malignant. The greatest blessings London could receive would be a good supply of water, proper sewerage, the removal of cesspools, and better ventilated dwellings.

25. Since your last examination before the Commissioners, have you considered the possibility of pointing out the track of the occurrence of cholera?—I think I could map out the track it would follow if the cholera should revisit us, as I fully believe it will; and Bermondsey would certainly be included in that map, together with Goulston-street, Church-lane, Bethnal-green, Rosemary-lane, Spitalfields, Wapping, Lambeth, and along the banks of the Thames, even in the City.

26. From what you know of the tenants of such property do you concur in the opinion that new charges or large demands for outlay, either upon the owner or occupier, would be nugatory?—Wholly so.

27. And you concur in the opinion that the object desired would be maintained by distributive charges, such as a charge of 2*d.* per week per house?—I think it would.

28. You therefore are of opinion that all means of economy, by a combination of work and a distribution of charges, will be essential to the prevention of such disease?—Certainly so.

29. Is it true that captains of vessels take out Thames water in preference to all other waters?—A few years ago such was almost the universal practice, but of late the belief in its superiority is considerably shaken,

some giving the preference to the Shaws water, Greenock; others to that from St. Helena, and others again believing that the water of the Ganges is quite as good as that of the Thames. Mr. Bowie.

Those who still prefer the Thames water say that, although it at first becomes very bad, after all the bad gases are thrown off it becomes as it were aërated by the marine atmosphere and again becomes very clear. This it is not so likely to do if kept in close towns and surrounded with impurities.

30. Will you ascertain from any captains why it is they prefer the Thames water to any other, and in what they think its particular advantages consist compared with the water of the Tagus or other river-water?—I shall endeavour to do so. Meantime I may mention that I have heard them say who prefer it that "it will keep good in climates where none else will keep."

31. Do the ships of the Royal Navy take their water from the Thames? —Water is supplied to the shipping in the Thames chiefly from the river itself. For large ships going long voyages or carrying passengers, it is generally filtered, or professed to be so, and sent on board in barges;* but for the smaller-class vessels no such precaution is taken; and while they are lying in the river it is dipped with pails and used for every purpose. Indeed, alongside the river, houses have no other water. This is surely a weighty reason for endeavouring to keep the river from pollution. The amount of disease occurring on board the shipping, and in the houses in the vicinity of the Thames, affords ample proof of the necessity of sanitary improvement. In an impure atmosphere good health is not to be expected: on the Thames, or in its vicinity, as it runs through the metropolis, a pure atmosphere is not to be found. Having on a former occasion expressed my opinion of the danger of making the river a common sewer, I shall merely add the following particulars concerning the use of Thames water in the Tower: "Beginning at the Seven-gun Battery, at the eastern gate, the water was very thick and discoloured, and actually alive. The water from a pump at the Spur Barrack stank so much that a horse or pig would scarcely have drunk it." "All the tanks, with the exception of one, were in a very bad state, and even in that one, which had a charcoal filter, animalculæ were perceptible." "Generally after having been pumped in two days it resembled milk and water, and could not be seen through." In this state however it was used for ordinary purposes. "The medical officer of the garrison recommended that spring-water from the Tower ditch should be used for drinking and culinary purposes, but the aged and the feeble would not take that trouble."

"The water supplied to the Tower was pumped from the Thames at a certain point within 200 yards of a sewer, the contents of which were all the blood and refuse from the butchers' shops and slaughter-houses in Whitechapel." "The soldiers and all the inhabitants of the Tower complained of the water, and attributed a great deal of the disease to the bad water." "A regiment that came from Chichester had eighteen on the sick-list three days after their arrival." The sickness

* It is not very unusual for a barge to go outside of the dock after having discharged the whole or a great portion of her load of water, and, by the withdrawal of a plug or two, soon re-enter, reladen; the water having been thus stealthily admitted without any filtration whatever.

Mr. Bowie. on that occasion was likewise attributed to the impurity of the water.

"The cases of cholera in the Tower were considered more malignant and rapid than in the worst parts of the Metropolitan Eastern District."

In compliance with the instructions contained in the 30th question, I have obtained the opinions of several sea-captains concerning the properties of waters of various rivers or water supplies used for long voyages.

Captain Coubrough, who has made many voyages to India, the West Indies, and other distant places, says "that the Thames water is generally considered the best for taking to sea, because, although it soon gets bad, it speedily recovers, even when kept in casks, especially by taking the bungs out and allowing the gases to escape. Putting it into iron tanks is another means used for sweetening it. In one of his ships there was an open pipe passed from the tank through the deck, allowing the escape of gas and the admission of air, by which the water was always kept sweet. The Shaws water, Greenock, keeps longer than that of the Thames; indeed, with proper care there is very little risk of its becoming putrid at all. A handful of lime was put into each cask at the time of filling, and the water kept good all the way to Port Phillip, a 5 months' voyage. For his own part, he does not think the Thames water superior to that of many other rivers."

Captain Potter gave the same account of the water of the Thames, Shaws, and Ganges, and thinks the St. Helena water of still greater purity.

Both Captains Coubrough and Potter stated that rain-water caught at sea from the ship's decks, sails, or awnings, however clean they may be, if put into a cask and bunged up, will become putrid in a few days, when, if the bung be withdrawn, the water will be full of vermin and flies, and the latter will fly out of the bunghole in myriads. This water, if put into iron tanks, will soon get sweet again. In warm weather, if there be any damp in any part of the ship, she will soon fill with flies and musquitoes even at sea. A damp cabin in a southern latitude is always full of them; in a dry one they are seldom seen. Captain Potter mentioned that scurvy is much more common in Bombay than Calcutta ships, although they are equally well found, and the voyage shorter to St. Helena. He has even known lady passengers so affected. This is no doubt owing to the badness of the water, it being all brackish when taken on board at Bombay.

An eminent shipowner and merchant told me that the Thames water was considered the best for taking to sea, as it soon purified itself; that when it became putrid it was very bad, and that the gas escaping from the bunghole could be ignited with a candle. He also stated that the process of putrefying and becoming sweet again, took place several times during the voyage. Since iron tanks were introduced he hears no complaints of the water, which is said always to be very good.

Captains Coubrough and Potter said that the preceding statement is quite correct as to what takes place with respect to the repeated changes in the water, and as to the gas being inflammable.

Captain Brown, stated that the Thames water, or indeed any water

generally taken to sea, may be sweetened when becoming putrid by exposing it to the air for a day or two. Mr. Bowie.

Captain Tasker, of the "Prince George," states that the description given by the preceding witnesses is quite correct, and adds, the water from the St. Lawrence at Montreal and Quebec so exactly resembles that of the Thames, that the difference could not be ascertained; and that it, like the Thames, receives the impurities of the towns.

Captain Hartley, of the "John Ormrod," says, "The chief part of the water supplied to the shipping at Bombay is rain-water. It is previously collected in stone tanks lined with Roman cement. These tanks are called buffalo tanks. The water in them is brackish, of a milky white colour, and covered with a green slime like what is seen on ditches in this country. The use of this water gives rise to and increases diarrhœa and dysentery. Besides the buffalo tanks there are two large reservoirs or tanks capable of containing 120,000 gallons, in which water is stored in case of drought. At Cronstadt the water is dipped out of the river in the same way as from the Thames. All the filth from the town runs into the river. The water is not half so good as that of the Thames. It is brackish, and causes or aggravates diarrhœa and dysentery. Has suffered severely himself from it both in Bombay and Cronstadt. St. Helena water and that of Ascension the finest got anywhere, although that from the Cape of Good Hope is nearly as good. Beautiful water is also had in New Holland and Hobart Town. At Whampoa the water, as taken out of the river, is very foul, worse than that of the Ganges. Last voyage from London the water was pumped direct out of the Thames."

Captain Skinner, a retired shipmaster, gives the preference to Thames water, because although it may sometimes be bad it soon gets right again. He says the water at Riga is very bad. It is of a reddish colour, supposed to be from the hemp, fibres of which are abundant in it. It is the general belief, that all those who use the Riga water, soon fall into diarrhœa, dysentery, or ague. Suffered very severely himself from diarrhœa, ending in dysentery, and has no doubt it was owing to the water. That the attack was a severe one, I can testify, having had him as a patient here afterwards, and almost despaired of his recovery.

Robert Bowie.

All the captains I have spoken to on the subject are unanimous in their opinion, that exposing putrid water to the air, renders it sweet. If this be the case, and there seems no doubt of it, a foul river must be a dangerous neighbour.

Letter from John Liddle, Esq.

Dear Sir, 4, *Alie Place*, 5*th January*, 1850.

There are several courts in the Whitechapel union which are without a supply of water. In all there is a deficient supply. The poor inhabitants are for the most part supplied with water from a stand-tap, the water from which flows daily for a short time (from one hour to three hours). Some of the houses where the poor reside Mr. Liddle.

[Mr. Liddle. are three stories high; and as the water only flows for a limited time in the court, the lodgers in the attics of these high houses must either go without water entirely, or obtain a limited supply, with a great deal of labour and loss of time.

In Johnson's charge, where more cases of illness have occurred than in any other locality in Whitechapel, the only supply of water for the inhabitants is a pump, the water from which is said to be unfit to drink, and the poor people are obliged to obtain their supply from a neighbouring court, and they have great difficulty in procuring it, the inhabitants objecting to let them have any.

In Cartwright-street the inhabitants are supplied from a well, the water from which is pumped into a tank, and pipes are connected with it, from which the butts in the houses in the neighbourhood are supplied. But the machinery is sometimes out of repair, and the inhabitants have then to obtain water elsewhere. In some instances the water-butt is adjacent to the privy.

In Hebrew-place and Love-court, Middlesex-street, the tenants of one of the landlords are without any supply of water except that which they may obtain from a pump. Here these poor people say that the water from the pump is so bad that they cannot use it, and they are obliged to beg it from their neighbours. In this case the landlord had a dispute with the Water Company, in consequence of their giving him notice to raise the water-rate during the rebuilding of some of the houses; alleging as the reason, that the quantity of water which was required for the mortar for the building of houses was much more than was needful for the occupants. The landlord resisted their demand, and the water was cut off.

In the month of August last a complaint was made by a party residing in the eastern extremity of Whitechapel, to the trustees, of the bad state of the water which was delivered into their premises. A sample of the water was shown to the trustees; it was most foul and fœtid. A committee of the trustees was appointed to make inquiries into the case, and found it as described. The Water Company was written to, and new pipes were laid down. Whether the company made any deduction from their annual charge I do not know.

The water which is delivered into my own house is unfit to drink, unless previously filtered. It is usually turbid. All complaints are of course useless. The only reply would be to a complaint, "If you don't like it we will cut it off."

Very truly yours,
(Signed) John Liddle.

P.S.—The trustees recently passed a resolution complaining of the bad quality, deficient quantity, and extravagant charge for watering the parish.

Alexander Bain, Esq.
Assistant Secretary, General Board of Health.

John Challice, Esq., Surgeon, examined.

Mr. Challice.

You are, I believe, a surgeon?—Yes.

Where do you reside?—In the Grange-road, Bermondsey; I am also chairman of the Bermondsey Board of Guardians, and have practised in Bermondsey for the last seven years, and largely among all classes.

You were of course called into active service during the cholera?—Yes, very much so.

Had you at the time any reason to believe that the extensive severity of the visitations of cholera in the district was influenced in any immediate degree by the supplies of water?—Yes.

Would you describe to the Commissioners the facts which led you to that conclusion?—The first fatal case of cholera that I met with was that of a master of a vessel at Gravesend. He was a fine man in the prime life, and in perfect health when he left London. He was going to the Baltic; he drank rather largely overnight parting with his owners and others, and he got up in the morning and drank heartily from one of the water-casks, which had just been filled with Thames water; he was soon after attacked with purging and vomiting. I went down post, and found him just dead. I asked particulars, and I found that the death was so sudden, that it almost appeared as if he had taken poison in the water; subsequently it was from facts that came almost hourly under notice that I formed the opinion of the direct consequences of taking impure water in producing a disordered state of the bowels, and those who had such a state of the bowels were pre-eminently in a condition to become victims to the disease.

Of course during an epidemic, when the general health is depressed, causes which have generally no perceptible effect materially affect population. Did you perceive these causes in action at the time you mention peculiarly?—Yes, undoubtedly; there was the case of a man who lived in the Coburg-road, in Camberwell parish, in a semi-detached house, in a healthy situation, and with a garden behind the premises; his wife had noticed that the water supplied to them was exceedingly bad, and, having been informed that it was likely to affect the health of her family, she invariably boiled and filtered it: all kept in perfect health except the father, who objected to drink this water, from its being flat and unaërated; he would still drink it as it came from the water-butt, and the consequence was that he was attacked with cholera-diarrhœa; he afterwards drank no more of it, and got well.

Then you consider this to be a fair example of the effects of using such water at such a time?—Yes; and I found that where deep-spring water alone was used, where such water was free from the effect of percolation from the drainage, persons escaped the cholera altogether.

Do you know what company supplied this water?—Either the Lambeth or Vauxhall.

I believe the one company filters the water, while the other does not, except by its subsidence?—I believe so; the water I speak of as it came in was filled with animalculæ before it was let into the tank.

Are not the water-butts and other receptacles often placed near the privies?—Yes, very generally.

Mr. Challice. Would not that alone be likely to contaminate water that might be pure at its source?—Yes, certainly; but here it came in with animalculæ in it.

But you think that the plan of receiving it in butts is bad?—Yes; the purest water under such circumstances would soon become impure, and a source of disease.

Have you observed the state of these water-butts?—Yes; very frequently.

Will you describe their appearance?—Generally speaking the wood becomes decomposed and covered with fungi; and, indeed, I can best describe their condition by terming them filthy. The poor people will not cleanse them; and if you look to their cooking utensils you will likewise see a quantity of dirt deposited.

Do you think that the deep-spring waters are free from animal impregnations?—I do; and, if used, would undoubtedly very materially diminish the extent of mortality: indeed, I entertain a very strong conviction that the general use of deep-spring water for human consumption would be of the greatest public benefit. During the prevalence of cholera, I repeat, in my own practice and experience it was the most powerful preservative against the epidemic.

Do you not think there would be this further effect from the supply of a purer water, that it would encourage a more extensive habit of drinking it?—Yes; the stomach is nauseated by bad water, and, being compelled to take a certain quantity of fluid daily, if the water does not agree with people they must take some other drink, such as beer, &c.

Does not that form the excuse with many of the labouring classes?—They could not do without other stimulants, if the water supplied in the neighbourhood is bad as well as the state of their dwellings.

Would you under such circumstances actually advise them to take alcoholic stimuli?—Undoubtedly I would.

Has the quality of the water supplied been at all improved?—I believe it has been much improved in appearance within the last two years. I think this is owing to an improved system of filtration.

Will you describe the way it came in before such improvement?—I have seen it come in looking nearly green, and smelling very bad; before I lived at Bermondsey I resided at this end of London. A young gentleman resided with me as pupil: he was a water-drinker, and had become so ill immediately after drinking the Thames water, that he was obliged to leave and go into the country. Afterwards he came back; but again became ill when he began again to take the same water, and he has always since been obliged to take a little brandy in the water, though he disliked it very much.

Then it is desirable, and indeed important, that the water supply should not only be clear and well aërated, but should also be what the French call "*appétissante?*"—Yes, certainly.

Charles Martin, Esq., Surgeon, examined.

Mr. Martin. 1. You are, I believe, a surgeon, residing in Bermondsey?—Yes, I am, and surgeon to the St. James's district.

2. Is there not within that district a place called Jacob's Island?—

Yes, but according to the new ecclesiastical arrangements, it is not in St. James's parish. Mr. Martin.

3. Was not that district very severely visited by cholera?—Very severely.

4. Can you give any idea of how many deaths occurred in that neighbourhood?—Some idea of the severity of the attack may be formed, when I state, that within the space of a few yards, nine persons lay dead at one period.

5. In consequence of your memorials to the Sewers Commission and to the Board of Health, did you obtain assistance for that district?—Yes, we did in July last.

6. Will you state what observations you made, with respect to the supply of water therein, and what effect the defective supply of water had upon the cholera?—I think in the greater number of houses there was no water to drink but that from the tidal ditches, until about July. At that time a great supply of water was laid on. It had been getting worse for years past; the water in the ditches becoming in some parts absolutely putrid, green, thick, and slimy. I know some clusters of houses where they had only such water to drink, and I know that out of five of those houses the inmates of four were affected with cholera. In all the early cases of cholera, the parties were found to have been supplied with water from these ditches. One case was that of a man from Maidstone, who stayed at a public-house in Mill-street for the night, on his way to Liverpool to emigrate; he arrived on the Saturday, and on Monday was attacked with cholera; in that house no water was laid on; great numbers of the houses in the neighbourhood are still not supplied with water.

7. Can you state whether other places in a similar position with respect to filth, but where they had a better supply of water, were so virulently attacked by cholera?—In the road they had a good quantity of water, but it was bad in quality. There is a nest of houses in that road, the road is 50 yards wide, and the inhabitants of all these houses had cholera one after the other. Yet all were supplied with water by the Water Company, and I cannot account for the result. Similar effects were seen in 1832 in the same street.

8. But may you be understood to state that the greatest intensity of cholera was found where the water was most impure?—Yes, most certainly.

9. Was the water supplied by the Company Thames water?—Yes, it was brought from Battersea.

10. Was it filtered water?—It cannot well be so, as I yesterday saw some of the water in West-street, which was thick and offensive, even at this time of year.

11. What is the character of the water generally given, such as is provided for drinking purposes?—It is sometimes very bad; it cannot be depended on. It cannot be filtered, for I have had brought to me fresh-water shrimps and even leeches which have been taken from it.

12. Is the water, to your knowledge, sometimes in such a condition as to discourage the use of water by the labouring classes?—I know that in West-street, only yesterday morning, one of the lodgers would not take his breakfast, because the water was so bad, that he could not drink it.

13. What have you heard with respect to the quality of the water?—

Mr. Martin. It is very hard; and I yesterday was told that linen washed in it had a yellow appearance, and they could not indeed wash well with it.

14. Where are the butts and tanks usually placed?—In the smaller houses they are usually very near the privies.

15. It is needless, then, to ask you, whether the water gets fresh pollution from such proximity?—It cannot fail to do so.

16. Has the drainage in the neighbourhood been at all improved?—In some of the streets it has been partially improved since July last; but still the smells in some places are very offensive.

17. Are there any soil-pans adopted?—Yes, in some places; but there is no supply of water for them, and they are still very defective.

18. It has been reported to the Board that at the Cloisters, Westminster, new drainage has been laid down, and that since then no offensive smells have been experienced, and that no refuse remains, that moreover there has been a distinguished improvement in the general tone of the health of the people residing in the neighbourhood: have you reason to believe that such was the natural result of such improvement?—I should quite believe that to be the case.

19. Suppose like improvements were to be carried out in Bermondsey and Jacob's Island, consisting of a good water supply, the abolition of cesspools, together with the application of house drainage, and a drainage of the foundation of the houses, with what difference of apprehension would you regard the approach of epidemic cholera or other epidemics?—Such improvements must tend to diminish the severity of the disease, whenever it may attack us.

20. From your experience of the cholera in 1832 and 1833, do you anticipate a recurrence of that epidemic in one form or another?—Judging from the past, most probably we shall have a return of the disease this year.

21. Have not epidemics been very severe in your district?—Yes.

22. Have you seen the table in the Registrar-General's Report, prepared by Mr. Edwards?—Yes.

23. Would you take that fairly to represent the respective liabilities to the disease?—Yes; I may mention one case in which the sewers water inundated a house during the summer and autumn, and the whole family have since been attacked with measles. And nearly all the inhabitants of this locality have since suffered from disease.

24. Then the representations contained in your memorials, urging the necessity of improvements being adopted in that neighbourhood are still in force?—Yes, for though much has been done, much more still remains to be done.

CHEMICAL.

Dr. Lyon Playfair.

Dr. Lyon Playfair examined.

1. Are you not chemist to the Museum of Practical Geology in the department of Her Majesty's Woods and Forests?—I am.

2. You have been engaged in analysing specimens of river, spring, and surface waters from different parts of the country?—Very extensively, and I have examined waters from most of the larger towns in the kingdom.

3. Have you been called on to analyse the Thames water?—I have

examined the Thames water as high as Henley, and also that delivered by the Chelsea and by the Lambeth Waterworks Companies. Dr. Lyon Playfair.

4. Will you state the general characteristics of the Thames water you have examined as to its hardness?—I have found the average hardness of the Thames water, from a mean of about 40 observations, to be between 13 and 14 degrees of hardness. I never found it above 16, and I have seen it as low as 11. It has been stated to average 16, but I have never found so high an average, although occasionally it may be so high. In two or three instances I have found it as low as 11, but this was due to accidental floods.

5. Have you analysed the water of the river Colne?—I have examined various streams at Watford, and I think the Colne among them. The Thames has some 17 or 20 tributary streams. They cannot be soft when the main stream is hard. I examined the degrees of hardness of the water at Henley every day for three weeks, and did not find any very great variation. One day the water was 16 degrees, but it generally ranged from 13 to 14.

6. Then you think it probable that, as other chemists state, it may reach 16?—I think that it does so only occasionally. I would not take the average of the Thames water, as delivered in London, to be more than 13, varying from 11 to 15.

7. It has been stated that the Thames water is likely to be affected by the sewage, and that about London Bridge is softer than higher up?—I should think it would become so by the mixture of sewage water. In fact analysis shows the presence of a much larger quantity of organic matter at London Bridge than higher up the stream.

8. You have probably seen other analyses by other chemists. Is there a general correspondence in them with regard to Thames water?—There is very little essential variation more than arises from waters being taken at different times and places, and I here hand in a table of these analyses.

Locality of the Water.	Sulphate of Potash.	Sulphate of Soda.	Chloride of Sodium.	Chloride of Potassium.	Chloride of Magnesium.	Carbonate of Magnesia.	Chloride of Calcium.	Carbonate of Lime.	Sulphate of Lime.	Silica.	Organic Matter.	Authority.
Henley . .	..	..	2·72	0·70	..	1·23	..	10·42	3·72	0·16	3·55	Playfair.
Twickenham.	0·67	2·00	..	..	..	1·02	1·75	12·76	0·45	0·27	3·48	Clark.
Brentford .	..	..	3·40	..	..	..	..	16·00	..	..	..	R. Phillips.
Barnes . .	..	..	1·70	..	..	..	..	16·90	..	..	..	,,
Putney . .	..	..	1·31	0·42	..	0·65	..	10·76	1·98	0·73	2·10	J. A. Phillips.
Chelsea . .	..	..	2·94	0·82	..	1·60	..	10·80	3·04	Trace.	4·25	Playfair.
London Bridge	0·27	3·10	2·37	..	0·08	..	6·97	8·12	..	..	6·99	Ashley.

9. There were some very old analyses, were there not, about the time of Dr. Bostock? has the analysis of water improved?—Yes; because many of the ingredients were not then thought of importance and are now included. In the previous table there are apparent discrepancies, because chemists view matters differently; thus Mr. Clark and Mr. Ashley unite their soda with sulphuric acid, while I prefer to view it as common salt, and the latter acid as combined with lime in the form of gypsum; these are only theoretical differences.

10. Are there not differences in waters appreciable to the senses, and

Dr. Lyon Playfair.

yet not appreciable by analysis?—Yes, certainly; I think the organic gaseous impurities in water have not yet been sufficiently examined by chemists.

11. Will not the sanitary effect of the difference of organic matter in water be very great?—I think very much more so than the effect of the mineral ingredients of the water. When waters contain sulphates, as they usually do, the organic matter acting upon them produces sulphuretted hydrogen, a putrid and noxious gas. The organic matter itself also enters into putridity, and innumerable instances of dysentery and diarrhœa have been traced to this vitiation of water. In the recent visitation of cholera, there was abundant evidence that numerous attacks were the consequences of the use of water containing organic matter in a state of decay.

12. Have you had any improvement in the analysis of organic matter in water?—A process has lately been described by Dr. Foschammer, which enables the amount of organic matter to be very readily determined.

13. Suppose you take the case of a susceptible child living on the side of a high hill, who was removed, without any alteration of diet, into a close atmosphere, would there not be found a great difference in its state of health?—Certainly. In this case the vitiated atmosphere charged with organic impurities exhibits a marked prejudicial effect, although there would be no very decided quantity of such ingredients detectable by chemical analysis. In fact, chemistry has not reached sufficiently far to isolate or examine them. We know they are present, because oil of vitriol is blackened by carbonaceous matter, when such air is drawn through it, but beyond the mere fact of its presence we know nothing.

14. Then that which has not yet by analysis been found by chemists will yet govern the quality of the air or of water?—So strong is my impression on this point, that in the midst of the cholera I urged it on the Board to warn the public against keeping water in the house, which though at first entirely pure, would, if kept in cisterns, absorb the vitiated air, and this would find its way, in a very active form, into the system of those who drank the water. In consequence of that recommendation the public were recommended to use boiled water, but that should be used at once, as it is more absorptive than water unboiled. The Chinese are well aware of the effect produced by boiling water containing organic impurities. They are accustomed to use boiled water for the purposes of drinking. A temperature of 212 degrees, that being the boiling point, is sufficient to destroy decay, so that boiled water loses the injurious influences due to the decaying matter which may be present.

15. Then the absorption of the air by water kept in cisterns or close rooms would be very considerable, and the taste of the water would be very likely to be altered?—Yes.

16. Have you any doubt that water exposed to an impure and noxious atmosphere is capable of absorbing noxious and impure matters, and thus proving injurious to the health?—I have no doubt of it; in fact, there is too ample experience in proof of it.

17. What sort of precautions did you recommend at the time of the cholera with respect to water?—I thought the most effective means of

avoiding injurious results would be to boil the water, if it were immediately used on cooling; it should be allowed to cool in a close vessel, because boiled water is more absorptive of all gaseous malaria than unboiled water. It is also advisable, though it does not remove danger to the full extent, to filter the water through charcoal, which removes a large proportion of the organic impurities. Dr. Lyon Playfair.

18. Of course at that time, knowing the effect of this absorption, you were alarmed at it?—I was, and I may mention one example of how water absorbs gaseous impurities. One of my assistants was making experiments with an oil, which had the smell of the concentrated urine of a male cat. The smell was insufferably offensive, and was so readily absorbed that it was impossible to drink the water placed in the room, and our clothes, especially the hair, were saturated with the smell, which did not disappear for several days. Every vessel containing a liquid in the room soon became contaminated with this horrible smell.

19. Then it is a great point that the delivery of water should be so managed as to avoid all such absorption?—Yes, certainly it should be so kept as to be always pure, cool, and palatable.

20. What rank would you assign to the Thames water taken as a river water?—The average hardness of water supplied to the various large towns of England is probably not less than 7 or 8 degrees. Accordingly the Thames water would be about 8 degrees above that average.

21. Have you found reason to modify your opinions as to the domestic value of soft water?—I speak with the force of increased experience when I say that I formerly greatly underrated the advantages of soft water. I need not allude to the importance of soft water for washing further than to say 30 ozs. of soap are consumed by every 100 gallons of Thames water before it forms a lather fitted for detergent purposes. The importance of soft water in cooking is less obvious, but no less ascertained to exercise an important influence on the culinary art. With regard to health, accurate observations have not yet been made, especially with reference to the human subjects, but, on animals, the effect of hard water is very apparent. Horses have an instinctive love for soft water, and refuse hard water if they can possibly get the former. Hard water produces a rough and staring coat on horses and renders them liable to gripes. Pigeons also refuse hard water if they obtain access to soft. Cleghorn states, that hard water in Minorca causes diseases in the system of certain animals, especially of sheep. So much are race-horses influenced by the quality of the water that it is not unfrequent to carry a supply of soft water to the locality in which the race is to take place, lest there being only hard water the horses should lose condition. Mr. Youatt, in his book called "The Horse," in remarking upon the desirableness of soft water for the horse, says, "Instinct or experience has made the horse himself conscious of this, for he will never drink hard water if he has access to soft; he will leave the most transparent water of the well for a river, although the water may be turbid, and even for the muddiest pool." And again, in another place, he says, "Hard water drawn fresh from the well will assuredly make the coat of a horse unaccustomed to it stare, and will not unfrequently gripe or further injure it."

Dr. Lyon Playfair.

22. On the whole, do you think that there are portions of the Thames from which the domestic supply of water ought not to be taken?—I think it unsafe to take it from below where the sewers enter into the river; but higher up the quantity of organic matter at present in Thames water is very inconsiderable.

23. Will you give a statement of the relative quantities of organic matter therein?—The amount of organic matter found in the water of the Thames is described in the table which I have already given.

24. Have you analyzed any artesian-well waters?—Yes, the water at Trafalgar-square, and since then, various deep well waters in London have been examined.

The following table gives the composition of three Artesian-well waters in London:—

—	Well at Combe and Delafield (Graham).	Well at Trafalgar-square (Abel and Rowney).	Well at Royal Mint (Brande).
Carbonate of Lime	6·18	3·25	3·50
Phosphate of Lime	0·19	0·03	. .
Perphosphate of Iron	0·24	. .	. .
Carbonate of Magnesia	1·08	2·25	1·50
Sulphate of Potash	. .	13·67	. .
Sulphate of Soda	24·25	8·75	13·14
Sulphate of Sodium	12·74	20·06	10·53
Phosphate of Soda	. .	0·29	. .
Carbonate of Soda	11·68	18·49	8·63
Silica	0·44	0·97	0·50
Organic Matter	. .	0·90	Traces.
	56·80	68·66	37·80

25. What are the general characteristics of artesian-well waters?—They are generally of five or six degrees of hardness; they also contain a large proportion of alkaline salts and common salt, but comparatively little earthy or calcareous matter. On an average not more than three or four grains of carbonate of lime, and two of magnesia are present in a gallon. Boiling deprives them altogether of their earthy salts, and renders them quite soft. Hence they are of much value for washing, for baths, &c.

26. Are there other qualities that make artesian-well waters of greater value than Thames water for drinking?—I do not think that they are objectionable for drinking purposes, though they contain a large quantity of alkaline salts. These act on the kidneys, but perhaps not notably in such small doses. The Trafalgar-square water has been lately used in all Government offices. The artesian-well waters are not always free from organic matter, but when they are very deep the quantity present is generally insignificant.

27. Do you concur in the general statement of the limited quantity of artesian-well water available for water supply to the metropolis?—Some of the manufacturers and brewers in the neighbourhood of London arrange to take the water required by them only on certain days, because the supply is so limited that the demand would exhaust it, and

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mutual injury must result. At Watford, 24 miles from London, the water in the wells is higher on Mondays than on other days. The brewers, and other large consumers of water, do not of course pump any on Sundays; and it is thus shown that the effect of the London demand extends as far as Watford, *a fortiori* it is much more exhausting in the immediate neighbourhood. Besides, Mr. Clutterbuck has shown, by numerous observations, that the water line of the London Chalk Basin has become permanently depressed by the increased demand upon it.

28. But without depending on artesian wells for the chief supply of London, might they not serve as a contribution for baths, &c.?—Yes, but too great a supply for these purposes might act injuriously on many manufacturers where they depend, as in the case of brewers, on the softness of the water. Although these might be supplied from elsewhere, still this would not be sufficient, as all their experience has been derived from the behaviour of a particular water; and if they were deprived of it, their success as manufacturers might be materially impaired.

29. Beyond the advantages you have stated to result from soft water, can you specify others from its use, for tea, for instance?—It is there of great importance; in fact tea cannot properly be made with the hard water, unless three or four times the quantity of tea were taken that would be required to make equally strong tea with soft water. The injurious effect of hard water is found not only in tea, but also in cooking, where soft water is of great importance.

30. As to artesian-well water, do its saline matters lower its value?—Not to a great extent, because when boiled it becomes soft water. Carbonate of soda being present, on ebullition all earthy matter is taken from the water, and it becomes soft.

31. Supposing an equal supply of artesian-well water were obtainable, would it be of great value?—No doubt, if it were in sufficient quantity; but it is not well calculated to supply cisterns on account of its phosphates, which promote the growth of vegetation. In Trafalgar-square the vegetation grows so that it would soon block up the entrance to the pipes if it were not removed. I was applied to by Government to give an opinion as to the propriety of supplying the Serpentine with that water, and I cautioned it as to an evil which would be found if it were used. This consisted in its disposition to encourage the growth of vegetation, which would give to the public the idea of putridity, and thus create a prejudice against the water.

32. But that vegetation would of course decompose?—Certainly; and acting on the sulphates present in the water, would produce sulphuretted hydrogen.

33. What is the difference in the proportions of organic matter in water, taken at one extreme of the Thames and the other?—I found as much as six or eight grains of organic matter per gallon down about London Bridge; and at Chelsea I found as much as four grains of organic matter, and about three at Henley.

34. Then you generally found the quantity increased as you approach London Bridge?—Generally.

35. Did you take the Chelsea water at any particular state of the tide?—I had it as it was flowing from the pipe into the cistern for the laboratory in Duke-street, Westminster.

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36. You stated that the Chelsea water is filtered?—It is.

37. What proportion would the degree of organic matter in that filtered water have to the general amount of organic matter in the usual London supplies of water?—On an average, it would be decidedly lower.

38. How is it at Henley?—About three grains per gallon; it is not what may be called a large average, still it is a notable quantity.

39. With regard to surface-waters, have you examined the water with which the print-works in Manchester and Liverpool are supplied?—Yes; and also the supplies to most of the large towns in Scotland.

40. Is the practice extending, of taking waters from surface-drainage?—Yes.

41. What, in general, is the value of such water, as compared with the water from rivers?—In general, where the water is principally flood-water, it is very much softer; for instance, Manchester is about to be supplied with surface drainage-water, and the hardness does not amount to 1 degree. Liverpool has also a Bill for the same purpose, and the water there will be under a degree. Sheffield likewise, to a certain extent, is supplied in the same way.

42. Have you ever been called on to examine certain waters in or near London?—Yes, at Richmond; I found the water from Richmond Park to be 8 degrees, and that from the Richmond Water-Works, taken from the Thames, to be 13 degrees of hardness. The surface water from the Bagshot sands is generally very soft, varying from less than one to two or three degrees of hardness. The hardness depends much on the nature of the soil. If I knew the nature of the rock on which the water falls, I think I could indicate what would be the degree of hardness. As far as I have seen, I have found surface waters decidedly softer than river waters.

43. As much as from a half to a third, the hardness of river water?—Yes, frequently; but it in a great degree depends on the geological formation. If there be no peculiarity of formation to make the water hard, surface-waters will be generally much softer than river-water.

44. Have you examined the drainage-water from land drains, that which is called shallow spring-water; and do you agree that this kind of water, properly managed, would have advantages even over the surface-water?—It would be all the better and clearer from having passed through a bed of vegetation, which would serve as a natural filtration. I should have no fear of surface-water (if it were carefully covered in) for the use of a town on a large scale, because it is found that in standing much of the impurity purifies itself by a natural process, and falls down.

45. Is it not the general practice now, where ground can be obtained free from building, to obtain a water supply from the collection of surface-water?—The chief supplies I know of lately are such, and they give not only sufficient in quantity but, on the whole, the best in quality.

46. Has the effect of drainage on surface-waters come before you?—No; I only know of Professor Wilson's analysis, showing the effect of land drains. I think you run the risk of getting a large amount of saline matter in water which is taken too near large towns. Suppose you select a piece of ground which is highly manured and limed; it has been shown that the kind of manure used is clearly exhibited in the

drainage-water of the field, and Professor Wilson recognized, by analysis, what each field was manured with, his object being to show that the fields were actually robbed thereby of the valuable qualities of the manure. I would sooner take the surface-waters if you could take them from a large extent of hill ground away from habitations, and consisting of non-calcareous formations. The recent observations of Professor Way have shown that claying soils have the power of extracting certain of the soluble saline ingredients of water, others of purifying them to a certain extent. Dr. Lyon Playfair.

47. Are you not aware that it has been stated that the water which has come down the colour of strong black tea, has, when passed through a bag of peat, become quite clear, whereas no sand-filter would materially alter it?—I am not aware that peat does so, but charcoal, and even certain kinds of trap-rock, possess this discolouring property.

48. As far as positive experiments go, the advantage is in favour of surface-waters?—Yes, if you have them economically, plentifully, and from proper localities. If you have a district very highly manured, I doubt the advisability of trusting to this source of supply.

49. The river-water may be said to be of two sorts, field-waters, and the waters from springs?—Yes it is so.

50. Suppose ground were obtainable near London of 100 miles square of sandy or gravelly quality; should you have any doubt that water superior to the Thames water could be obtained?—I should not like to give an opinion without inspecting the district. If you refer to the Bagshot sand, I may state, that having examined the district, I do not see any chemical reason why its water should not be of excellent quality, as it is of undoubted softness.

51. Is it a general conclusion as to Thames water, that it is above the average in organic matter, and that sewage water, in particular parts, is in excess?—I have no doubt of it.

On the Air and Water of Towns. By Robert Angus Smith, Ph. D., Manchester.

Having been requested to examine into the variations in composition of the air and water of towns, I send the observations which I have made upon the subject. Dr. Robert Angus Smith.

It has been long believed that the air and the water have a most important influence on our health, and superstitions have therefore constantly been attaching themselves to receptacles of the one and emanations of the other. The town has always been found to differ from the country; this general feeling is a more decisive experiment than any that can be made in a laboratory. Although men of high standing have been found to deny that any difference exists between the air of the worst towns or the most crowded rooms and that of the open country, it seems to be only a proof, that men accustomed to experimental inquiry are apt to forget the value and force to be attached to those apparently less rigorous observations which the senses are constantly and unconsciously making, and to believe only that which can be demonstrated by the grosser processes of a laboratory. Most men would be satisfied of the impurity of an atmosphere through which a blue sky could never be seen of a blue

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colour, or where a bright cloud appears of a dingy brown; but there are men who take this air into glass receivers, and because they detect no new substances or strange compounds, they deny that there is any peculiarity. I have known persons from the highlands of Scotland who felt in going into Glasgow as we do when going into a glass-house or forge, and who could not be persuaded to stay, unless they remained long enough to find some advantages before unknown to them. The inquiries made by the Sanitary Commissioners have completely established the fact that crowded towns are dangerous places; and although it is still an open question whether a well-regulated town or country life be the more healthy, it is sufficiently established that our towns have subjected themselves to many dangers, which we in self-defence are feeling compelled to try to avert, by acting according to natural laws as far as their acquaintance has been made.

Most persons must have felt that a rapid entrance into a large town, especially a manufacturing town, was also an entrance into another climate. An inhabitant of the sea-coast or of the hills perceives it rapidly, and the effect on them is often decidedly bad; to those accustomed to it a few hours are found to be enough to cause them to forget the atmosphere which in their holiday excursions had caused them such delight. We are apt in these cases to assign other reasons for the feelings experienced, and to attribute much to the change of scene and occupation; and I have read it not long ago asserted, that the air in the streets of London and of the tops of distant hills, probably differed only in the temperature.

Priestley found that after shutting up a mouse in air a considerable time it seemed to become weak and to be slowly dying, but if he put a fresh mouse into the same air at this period it instantly died. We can bear the gradual deterioration with ease, but we often find ourselves surprised at the state of the air in which we find our friends sitting, perfectly unconscious of any want of attention to their sanitary state.

The air has often been called a general receptacle for all impurity; Nature has made it a universal purifier by giving it so large an amount of free oxygen. It is oxygen which purifies, and bodies which are impure have a tendency to volatilize, after which they become pure.

No doubt the air of a town contains a portion of all exhalations which arise in a town. These are such as come from living bodies in the first instance; exhalations which can never be got rid of, but which it is probable are not at all dangerous, unless accumulated. There are also exhalations from the refuse matter of animals, and from combustion of fuel. These are the chief points. Various manufactures give out various effluvia, and no man that has walked through a large town with attention can have failed to perceive that no street is entirely free from effluvia, and that every one seems to have a peculiarity of its own.

The smell is a delicate guide to this, and although custom causes us to forget that odour to which we are much exposed, a frequent change gives us still more acuteness, and both houses and streets may fairly be complained of when the inhabitants are little aware of it.

That animals constantly give out a quantity of solid organic matter from the lungs may readily be proved by breathing through a tube into a bottle, when the liquid or condensed breath will be collected at the bottom of the bottle; or by breathing through a tube into water, when a

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solution of the same substance will be found in the water. This would scarcely require proof if we considered that breath so frequently has an organic smell; perhaps, rather, it always has an organic smell, and when it is bad the smell is often offensive, containing decomposing organic matter.

If this condensed breath be put on a piece of platinum, or on a piece of white porcelain, and burnt, the charcoal which remains and the smell of organic matter will be conclusive. If it be allowed to stand for a few days (about a week is enough), it will then show itself more decidedly by becoming the abode of small animals. These are rather to be styled animalcules, and very small ones certainly, unless a considerable quantity of liquid be obtained: they may be seen with a good microscope. Animalcules are now generally believed to come from the atmosphere and to deposit themselves on convenient feeding-places; that is, they only appear where there is food or materials for their growth, and they prove, of course, the existence of that continuation of elements necessary for organic life. At the same time, their presence is a proof of decomposing matter, as their production is one of the various ways in which organized structure may be broken up. Such a liquid must of course be an injurious substance, giving out constantly vapours of an unwholesome kind.

I mentioned some time ago that I had got a quantity of organic matter from the windows of a crowded room, and I have since frequently repeated the experiment. This matter condenses on the glass and walls in cold weather, and may be taken up by means of a pipette. If allowed to stand some time, it forms a thick, apparently glutinous mass; but when this is examined by a microscope, it is seen to be a closely-matted confervoid growth, or in other words, the organic matter is converted into confervæ, as it probably would have been converted into any kind of vegetation that happened to take root. Between the stalks of these confervæ are to be seen a number of greenish globules constantly moving about, various species of Volvox, accompanied also by monads many times smaller. When this happens, the scene is certainly lively and the sight beautiful; but before this occurs, the odour of perspiration may be distinctly perceived, especially if the vessel containing the liquid be placed in boiling water.

My analyses of this body are not yet ready, further than that it contains the usual organic elements.

If air be passed through water a certain amount of this material is obtained, but I have found it difficult to pass a sufficient quantity through. If it is made to pass rapidly, absorption does not take place, and evaporation of the water is the consequence; if it passes slowly, it requires many weeks to pass 100 cubic feet through a small quantity of water. I continued the experiment for three months, but although I obtained sulphuric acid, chlorine, and a substance resembling impure albumen, I did not get enough to make a complete examination; and indeed this could not be expected, as I found that in that time less than 1,000 gallons of air had passed through.

When this exhalation from animals is condensed on a cold body, it in course of time dries up, and leaves a somewhat glutinous organic plaster; we often see a substance of this nature on the furniture of dirty houses, and in this case there is always a disagreeable smell perceptible. I

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have no doubt that this is a great cause of the necessity for constant cleaning, which experience has found and made to be a very general practice in England and elsewhere. In other words, it is a reason why that which is not cleaned becomes dirty, a question which I have often felt great difficulty in answering.

Water is necessary to the spontaneous decomposition of animal matter, and it is probable that in a warm climate this coating of walls and furniture would not be so dangerous as with us, where everything is exposed to moisture a considerable part of the year. In a warmer climate it will probably be diffused more into the atmosphere, and not be so much retained as it is by the moisture which dissolves it or to which it attaches itself.

It will probably be found that this substance is not poisonous if taken into the stomach, but it is known to be poisonous breathed into the lungs, as we know crowded rooms are. The quantity is small that we do breathe, but at the same time we must remember that it is diffused in air, and has therefore a surface as extended as the volume of the air in all probability; and we know that a cubic inch of sulphuretted hydrogen will scent at least some hundred cubic feet of air.

As this substance of which we speak is organic, and contains carbon, hydrogen, and nitrogen, with other elements, it is capable of oxidation; and it no doubt is continually undergoing oxidation in the air, probably forming carbonic acid, water, and ammonia. It is also not unlikely that this is a greater source of the ammonia of the atmosphere than the mere fœtid decomposition of animal matter, which does not occur to a large extent in nature, provision being made for its removal by animals, and by vegetation especially.

Organic matter in contact with water constantly gives off an odour of some kind, and especially if heated, so that it would appear as if steam or vapour were capable of taking up much more than that which we call volatile matter.

If organic matter be allowed to decompose in the air it gives out carbonic acid, ammonia, sulphuretted hydrogen, and probably other gases. Priestley has shown that if it decomposes in water it gives out an inflammable gas. If, however, it be exposed to the action of soil, other circumstances being favourable, it is converted partly into nitric acid.

None of these cases occur purely in our towns, but all of them occur to some extent. Carbonic acid and ammonia occur in all reservoirs of refuse, and sulphuretted hydrogen occurs also in abundance. It was once very perceptible in London, as Sir Kenelm Digby complains much of the state of the streets, when silver could not be kept clean in his day. This may be observed now in many towns, and is, in fact, not uncommon. This is a disagreeable smelling gas, and wherever it is abundant, will be easily detected by the nose. It may be detected readily in many courts and alleys, also at the mouths of sewers, and in some parts of the Irwell and Medlock, at Manchester, where they are filled with organic matter and alkaline, and earthy salts. Ammonia generally accompanies it, so as to diminish its bad effects.

Ammonia itself is probably of no injury unless in excessive quantities, and may be considered as one of the most wholesome forms in which nitrogen and hydrogen, as gases, pass into the air. A decomposition

such as this occurs ordinarily in towns, as there is a certain exposure to air always. Dr. Robert Angus Smith

In cases where there is no exposure, or, at least, when the substance is in water, inflammable gases are produced, as Priestley has shown, and Liebig has, to some extent, explained. It would seem as if, when decomposition commenced, oxidation of one portion necessarily took place, leaving the other portions without oxygen, unless in cases where an abundance could be obtained. Dalton found the gas from the floating island at Derwentwater to contain carburetted hydrogen and nitrogen. The carbon and the hydrogen are deprived of oxygen entirely, whilst more oxidized bodies, as carbonic acid and humus, are left, the latter body to be in time entirely oxidized, as Liebig has shown. Whether the nitrogen comes off alone or as ammonia, the same division of a substance into oxidized and deoxidized occurs, as we see, in the fermentation of sugar, where carbonic acid a body oxidized, and alcohol a body to a great extent deoxidized, occur. We have only to suppose compounds of carbon, hydrogen, and nitrogen, coming from decomposing matter, to show us the great danger. It is not to be trusted that these bodies always appear in the mode of combination mentioned here; their modes of combining are various, and these elements form the most active poisons known to us.

A certain amount of moisture is almost essential to the escape of odour from many bodies; it probably arises from two causes. The vapour of water is a vehicle for organic matter, and water favours decomposition in bodies, so that as they decompose the vapour is given out. From whatever cause, it will be found that moisture rapidly facilitates the escape of odour. Mineralogists avail themselves of this when they breathe on a mineral, and then ascertain the smell. The moisture of an evening, or even artificial moisture, causes the flowers to give their scents, and the moist state of the atmosphere before or after a shower, causes also a great fragrance in a flower-garden. But whilst this is caused, the same laws are operating for injurious effects, wherever there is a reservoir of putrid matter, for then the exhalations are also abundant, and bubbles may be seen to rise from filthy water. It is not improbable that the state of the atmospheric pressure may cause this, as Mr. E. W. Binney has shown that the gases in coal-pits are caused to escape rapidly during a lowering of the barometer. Bodies that are moist will therefore give out more organic vapours; if there be abundance of water, as in a lake, the vapours would to a great extent be dissolved, even if the same kind of decomposition were to proceed as in merely moist or marshy ground. We might expect then that soil, if moist, will give out, not pure vapour of water, but water with organic matter in it. Wet soil is a little acid generally, and if very acid is bad land, sour as it is called; but if made alkaline, either by the direct adding of ammonia, or by decomposition producing ammonia, it becomes fertile. If any alkali be added, which gives out ammonia by decomposing the humate of ammonia in the ground, the same state of fertility is attained. This end is generally attained by adding lime. This state of almost neutrality of the soil is also regulated by nature, and a fertile alkalinity obtained by the rapid decomposition of organic matter through moisture and heat. In this alkaline and warm state more vapours will of course be given off, and the ammonia will assist in the removing of organic matter into the air. How far this

Dr. Robert Angus Smith —— occurs on sowed land has not yet been seen by me satisfactorily; but on peat land the ammonia formed is abundant in hot weather, so much so as to be perceptible directly by the senses, and to take with it in solution a large quantity of humus and salts of humus, containing food for plants, as I showed in a paper to the Philosophical Society of Manchester.

I mention this to show how organic matter may be lifted into the air, and why hot weather promotes it; also, I wish to show how various this matter must be in its properties, as all vegetable solutions give out a certain amount of matter from them.

To ascertain if organic matter were really to be got from such vapours from land, I collected some dew by condensing it on a glass cylinder, and allowing it to drop into a glass below. The fewness of the evenings favourable for the purpose this year, has, of course, retarded me. I saw plainly, however, that the substance thus obtained from the dew was very different from that obtained by condensation in a warm room; whereas that from a crowded room was thick, oily, and smelling of perspiration, capable of decomposition, and productive of animalcules and confervæ; the dew was beautifully clear and limpid. When boiled down, the odour was not disagreeable, and I may say, not remarkable; but when the small portion of solid matter, which remained dissolved in it was exposed to heat, the smell was that of vegetable matter, with very little trace of any nitrogenized substance. It was also rather agreeable than otherwise. The dew was collected in a flower-garden, and I have no doubt in favourable weather of being able, in dissimilar situations, of getting it of different characters. It is not improbable that the matter in the dew may be a measure of the amount in the atmosphere; if so, the decided difference between that of the country and that of crowded rooms is to be remarked, and may probably form a good guide towards a knowledge of comparative purity of atmosphere.

In walking along the fields on an evening when there is much dew, it may be observed how much effect a dry soil has; indeed, I might almost say the climate of a field will be found to vary almost every yard. Every cause of cold, the formation of a drain, the lowness of any spot, its being higher or more level, or more sheltered, is indicated by this delicate thermometer, the rise of vapour, and the perception of cold. If we ascend higher the same is seen on a larger scale—on miles instead of yards. A house may be in a clear atmosphere, and the lawn before it in an impenetrable fog. One foot in height makes a difference, and one foot also of level distance, if the ground should differ in quality. The damper places give us a feeling of freshness, and cause also a slight irritation of the nose. Every wall causes a certain amount of dampness; and even in a windy day, a leafless hedge will protect one side from evaporation. In these respects, therefore, we may say truly, that every field or house in the country, as well as I believe every house in the town, has its own peculiar climate.

The effect of wetness on the atmosphere of a town is very great; if we observe the smoke on a dry day we find that it rises, and if there be a little wind it is carried out in distinct black lines, leaving the air below comparatively pure. If the day be dull and wet, the smoke instead of being carried away is poured out directly into the streets, and a spectator at a short distance sees a basin of black fluid, if the town be in a valley, or a heap gradually diminishing towards the circumference as it falls into

the adjacent country. It may be replied, that the diffusion of gases would prevent this, but again it may simply be said that it does not prevent it. Besides, the smoke is not to be considered as a gas, the black portion is carbon and tar. If the carbon is wet, it becomes, like all other spongy bodies when filled with water, heavy, and of course falls down. The carbonic acid will no doubt be diffused more, but it also is strongly attracted by water, and must not be viewed as a pure gas, such as oxygen or nitrogen. Probably this is the reason of the very disagreeable state of our towns in damp gloomy weather; it is such weather as does not allow the town to be ventilated. The same does not occur on a thoroughly wet day, when the matter is carried fairly down into the streets, and a certain freshness is perceived. Dr. Robert Angus Smith.

Rain amidst smoke is just such a liquid as we might expect; it is a mixture of soot in a finely-divided, apparently dissolved state. It is, however, not dissolved, and by boiling down may be got free. It is not easy to tell exactly the composition of the rain; for, although I have examined it, and obtained many products in it, so much may be said to come from other sources when water is collected near houses or near the ground, that I have often suspected some source of error. However, I think if we take that rain which is collected on a very wet day, after many hours of continued pouring without wind, we may consider that we have got the purest specimen. This was collected frequently, and having obtained it so often I am now satisfied that the dust really comes down with the purest rain, and that it is simply coal ashes. No doubt this accounts for the quantity of sulphates and of chlorides in the rain, and for the soot, which are the chief ingredients. This rain is also often alkaline, arising probably from the ammonia of the burnt coal, which is, no doubt, a valuable agent for neutralizing the sulphuric acid so often formed. It must, however, be frequently acid with sulphuric acid, although I have not found it so, as I have traced sulphurous acid in the atmosphere frequently, walking through some miles of streets to come to its source. The source, however, is not easily obtained, because I believe it does not fall till at some distance.

The rain-water at Manchester is about 2¼ degrees of hardness, harder in fact, than the water from the neighbouring hills, which the town intends to use. This can only arise from the ingredients obtained in the town atmosphere.

But the most curious point is the fact that organic matter is never absent, although the rain be continued for whole days. This matter is capable of promoting animalcular life to some extent, and small specimens may be seen moving solitary in it. If allowed to stand in a bottle, this may be more clearly detected. On this matter I must say more at a future time.

My chief wish is to show that the general notions entertained by persons as to the air of towns are not without the support of what is called scientific observation, although at the same time the effects on life are greater than chemists by any observations could have made out.

Vogel and others have found organic matter in the atmosphere; and Dr. Southwood Smith, in looking for matter which might produce fever, found an organic substance, I believe, in some of the streets of London. I give only in detail what I have myself observed.

If this matter should from any cause be exposed to a decomposition

Dr. Robert Angus Smith. —— more rapid than usual, we have before us a state of things worse, because more general than a bad sewer, and can account for many diseases. I am, therefore, disposed to think of it as Lord Bacon thought of the cause of jail fever:—"Out of question such smells consist of man's flesh or sweat putrefied. There may be great danger of such compositions in great meetings of people within houses; for poisoning of air is no less dangerous than poisoning of water. And these empoisonments of air are more dangerous in meetings of people, because the much breath of people doth further the reception of the infection."—Bacon's *Sylva Sylvarum.*

The state of the air is closely connected with that of the water; what the air contains the water may absorb, what the water has dissolved or absorbed it may give out to the air. Whatever the rain meets with in its course from the surface to the wells of a town is, if soluble, dissolved in the water. The enormous quantity of impure matter filtering from all parts of a large town into its many natural and artificial outlets, does at first view present us with a terrible picture of our underground sources of water. But when we examine the soil of a town, we do not find the state of matters to present that exaggerated character which we might suppose.

I have often been struck with the extent to which water may purify itself. At Bala, on the hills, the water is brown; in the lake it is still coloured, but in its course it becomes beautifully clear. A still stronger instance may be observed on the hills beyond Bolton, the water in which is of a deep brown; when it falls into the reservoirs just below, it ceases to be very dark, although still too brown for agreeable use; but when it has run a few miles it ceases to be remarkable, and is often perfectly pure. I was struck also with the fact that filters do not become dirty in proportion to the amount of impurity which they seem to remove. The sand at the Chelsea Waterworks contain only 1·43 per cent. of organic and volatile matter after being used for weeks, and cannot be considered as impure in a high degree.

In 1827, Liebig found nitrates in twelve wells in Giessen, but none in wells 200 or 300 yards from the town (Annales de Chimie, vol. xxxv.) Berzelius made similar observations at Stockholm. In 1846 and 1847, I examined about 30 wells in Manchester, and found none free from nitrates; many contained a surprising quantity, and were very nauseous (Mem. of the Chem. Soc.).

Wells in the country generally contain organic matter, and in the town the organic matter is oxidized into nitric acid, as if it required a certain intensity to promote the action. It is very probable that this acid is an effect of restricted oxidation, occurring as it does with such excess of organic matter, and, although near the surface, still under hard pavements and soil where there is also little flow of water. It might, however, be viewed as an oxidation, with excess of oxygen also where the large extent of surface presented by the porous materials gives an increased facility for oxidation, or rather presents compressed oxygen, so as to be more effective.

It will be of interest to know what becomes of the carbon and hydrogen in these cases, if they are removed together. These nitrates do not occur to any extent in purifying large bodies of water, nor do they occur in filtering through rocks or sand as in nature, but they occur in more close situations, under streets and houses, and in undrained ground,

according as it is saturated with animal matter. It is found in sewer water, in the Thames water, and in all dirty streams into which sewers empty themselves: perhaps the reason of its not being found in larger quantities in streams from drained land is simply the want of animal matter, or it may not be formed more rapidly than the plants can use. It is found, however, in wells which are situated in well-manured gardens, and in all wells at the backs of houses, without any exception yet met with by me.

The wells of private houses, and we may say wells generally, are placed in that spot which of all others is the worst, the cesspools and the wells always too near, generally close to each other. I was first led to examine this from a complaint made in Manchester, where a case of this kind furnished water of an oily appearance, containing about 90 grains of matter in a gallon, and being excessively disagreeable. The same well was examined in summer, and the matter had risen up to nearly an ounce in a gallon. The well was of course not fit for use in this state.

In the same neighbourhood was a churchyard, and around it I examined five wells, one of them especially, sufficiently far removed from cesspools to make me believe that the churchyard was the only cause of the impurity. The wells of London all contain nitric acid to a certain extent, but they vary exceedingly in the amount. The following have only a small quantity :—Exchange, Rood-lane, Eastcheap, St. Paul's-churchyard, Tower-hill, Covent-garden, Lincoln's Inn-court, St. Clement's Strand, Aldgate Pump, and Bow Church. It seemed to me, from the situation of the old well at Clerkenwell, that it was very well fitted for obtaining nitrates, and on examination it was found to be exceedingly well-filled with earthy salts, containing 148 grains of solid matter to the gallon, of which several were nitrate of lime. The water of this neighbourhood would contain about 20 grains to the gallon in a natural state, if we may judge from the water generally found in the valley of the Thames.

Another well in North-street, Tottenham Court-road, was examined, as from the state of the drainage I expected it to contain a considerable quantity of earthy salts. Here also I was not deceived, having got 130 grains of sulphates, chlorides, and nitrates in a gallon; the water itself a fluid which I could not swallow.

There is then a constant formation of nitric acid under towns. It is a little surprising that organic matter, properly so called, should not be found in those wells; the nearest to a source of organic matter do actually contain the least, because in these cases it is more readily converted into nitric acid, which may very properly be called here oxidized organic matter. At the same time, also, it must be remembered that the nitrates decompose any organic matter present if heat be applied, so that no blackening of the residue can be perceived. Those wells of London first mentioned do not contain much of these salts, but sufficient to deprive them of organic matter, as no vegetation is to be perceived in them, even by a microscope, after a long period. If, however, a mere trace of nitric acid be found, as in the well of Tower-hill, a green matter deposits on standing. This perfect freedom from animal or vegetable growth is a ground for suspicion, also, of nitrates being present, as there generally is a little green matter found in the purest waters, unless they pass through great depths of sand or gravel, as in the new red sandstone, where the

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water, if taken from a deep well, is entirely free from everything but inorganic salts.

The fact of some of the wells being freer than others from these salts is a proof of a dependance on the state of the soil, and I doubt not that the drainage has the greatest effect on the change made. Some of the mud taken from under a street in Manchester, where a sewer had been allowing some moisture to ooze out, was found to contain nitrates also in considerable quantities, but the sand and gravel below was nearly dry, and perfectly free from nitrates. Although it is very probable that nitric acid is formed most readily in the sand, yet it is also more readily carried away, and after much rain we cannot expect to find such a soluble salt remaining.

As to the source of this acid, I made some experiments last year for the Metropolitan Sanitary Commission, which I may here relate. My object was to get an idea of the nature of filtration. A jar, open at both ends, such as is used with an air-pump, was filled with sand, and some putrid yeast, which contained no nitric acid, was mixed with pure water and poured on the sand, allowing it to filter through. The product of nitric acid was abundant, so much so, as when boiled down to give it out at once, on the addition of protosulphate of iron and sulphuric acid, making the red fumes of the peroxide of nitrogen apparent without the aid of any very refined test.

Charcoal was tried for the same end; it did not answer, although allowed to act for two months; it was put into a large Hessian crucible, and the liquid allowed to trickle through the crucible and charcoal together.

Ox-flesh was in this manner oxidized into nitric acid, after allowing it to putrefy. This result could be obtained by means of an ordinary household filter, if the time allowed were long enough, and other conditions favourable. The same was done on a smaller scale, by allowing nitrogenous organic matter to stand over spongy platinum.

No doubt this is a very important provision of nature for the prevention of the evil consequences of putrefaction; it is the complete destruction of all dangerous gases, and the perfect purification of the most impure substances; whether it be advisable to drink water having much of this oxidized matter in it is another question. We see, however, in this the two great agents of sanitary improvement at work for us, the air and the water acting through the soil; whatever goes through such an ordeal is made pure. The drainage of a country is therefore that which removes the evil effects of decomposition as well as the excess of moisture.

The action of air and water on *surface* is then a powerful one, and probably is capable of doing many marvellous things with the substances given to it to treat. The effect produced on sulphuretted hydrogen is no less decided. A bottle of strong sulphuretted hydrogen was poured upon the sand-filter, and sulphuric acid was the result, with sulphates formed of bases which it had washed out of the sand. Sulphuret of ammonium filtered through sand contains sulphuretted hydrogen no longer, and will not blacken lead, so powerful is this kind of oxidation.

Water from a pump in a yard not far from me gave out a disagreeable smell of sulphuretted hydrogen which filled the neighbouring houses. This I found the persons accustomed to filter and to drink:

the sulphur was converted into sulphuric acid, and the water was actually made quite pure.

These are no doubt some of the advantages of a filter; if so, we are then to consider that a filter acts according to its cubic dimensions, and not by its surface only. If the porous rocks have thus the power of oxidizing sulphur and nitrogen, we may then ask, have they not also the power of oxidizing carbon? Hydrogen is no doubt oxidized, the ammonia being broken up so as to form oxides, as nitric acid and water.

We see that natural filtration, with abundance of room and free movements, dissipates the organic matter, and nitric acid too, if ever formed. The time allowed for filtration being so short, that is, the time from the falling of the rain to the appearance of the pure water from the spring, we cannot suppose that vegetation accomplishes the purification, whilst there is no deposit of impurity apparent to account for the change. It seems to me that the action of the compressed air on the surface of bodies is sufficient to answer this question, and that this matter is removed by a process of oxidation. It was Saussure who showed that humus can unite oxygen and hydrogen; Liebig has shown that humus is constantly capable of combining with oxygen, and calls it a constant source of carbonic acid. When then we see water not very free from organic matter enter a rock and come out free from organic matter and sparkling with carbonic acid, leaving no visible organic impurities behind it, we may safely conclude that the oxidation of the carbon has effected it; this then is a higher degree of purification than the oxidation of the nitrogen, which is probably allowed to go free.

Processes such as these are going on constantly wherever water is filtering. On land generally such things must be constantly occurring. The ditch-water of our fields is a very different water from the river-water into which it runs, or even of the drains a few feet only below it. Some water taken from a ditch in the neighbourhood of Manchester became in a few days a complete mass of life, and the many specimens of animalcules in such water make it a good subject of study. Water from a drain three yards deep does not, however, contain this immense quantity of organic or organizable matter, depositing only some green matter, partly animal, partly vegetable.

When water flows from hills or elevated land in a river-course, it undergoes changes according to the nature of the bed, and also according to the number of towns on its banks. As an instance of this, I will follow the river Thames from its sources to London Bridge without giving the details of analysis here, but the character of the changes as known to me.

Water from the Seven Springs, or from Thames Head, or Andover Ford, proceeding as it does from the rock, is in the perfectly oxidized state of which we have been speaking; it contains a great deal of carbonic acid and of lime in solution. When allowed to stand, it preserves its great purity (or clearness of appearance rather) any length of time, not appearing to change. Such water as this requires no managing; it would be a good thing if it could at once be introduced into houses; it is in fact spring-water from the rock, and such water is known to be always good, unless the rock contain deleterious substances. Rocks of course are found which give out a water much freer from lime than the water of

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the Thames sources; such, for example, as those between Lancashire and Yorkshire. At a place called Swineshaw on one of these hills, a stream gushed out from the hard and insoluble rough rock of this place, having the purity of average distilled water, with a sparkling appearance and agreeableness to the palate which distilled water never has. It is under one degree of hardness of Clark's test. No doubt there are other streams as good, and the whole of that and similar districts gives the most beautiful water. The same may be said of a great deal of the water of North Wales, and in such places as have very insoluble rocks. I said as pure as the average distilled water; it may not be known to all persons, that a number of distillations are necessary in order to obtain pure water. For this purpose, a water from a great depth, or a spring-water from a rock is best to use, as there is less volatile and organic matter in it; the first distillation of the usual waters about Manchester giving a very imperfect product.

Purity of water and fertility of soil are not to be expected together, if we may judge from the facts above. Freedom from both inorganic and organic matters is got only in water from very insoluble rocks, which are not the fittest for vegetation; or it is got where there is much sand or gravel containing little soluble matter, and of course little food for plants. If, however, these strata be together, as soon as the water comes from the insoluble to the soluble it will change.

The Thames water is at first pure, as far as freedom from organic matter occurs, and takes its course through a rather level country. The stream is soon filled with plants; and at Kemble the water has already taken up some organic matter, enough to form a slight green deposit on standing. The water here is still beautifully clear, and is good water; it is 15·5 degrees of hardness.

When we come down to Pangbourne, the water cannot be said to have become much worse; it is still so pure as to require a considerable time to form a deposit, and that only small, containing a few plants and some small animalcules from $\frac{1}{2000}$ to $\frac{1}{8000}$ of an inch. Here there is a slight but still decided trace of organic matter from animals. There has been an increase in the hardness also.

			Grains of Soap.
Seven Springs	12·75	of hardness	262
Andover Ford	13·88	,,	283
Thames Head at Kemble .	15·5	,,	312
Church at Cirencester . .	15·7	,,	315
Reading	16·5	,,	340

Pangbourne was only 15·4 in November, 1847; the others are of February, 1848, when the water was harder down to London. There is seen here an increase in hardness, and there is also an increase in soluble salts not contributing to the hardness. At Seven Springs the hardness is equal to the whole amount of insoluble salts and a fraction more, which may arise from an excess of carbonic acid.

			Grains.
At Seven Springs	inorganic matter	in a gallon	12·25
At Pangbourne	,,	,,	22·33
At Reading	,,	,,	23·114

At Windsor, animalcules begin to show themselves more prominently in the water, and these rather large hydatina. There are also at Reading and Oxford some of the smaller green naviculæ, and several other smaller

green bacillaria. Oxford water had more of these than Reading, and also a large amount of matter in solution; it is probable that the soil through which the Isis flows is rather different from the other part of the Thames. The river was rather high at the time.

From Richmond downwards the case is much altered, and the water, although clear, gives after a time, a brown flocculent deposit, entirely distinct from the mud deposit, which has been carefully removed beforehand. This flocculent deposit contains many animals, large and gelatinous-looking; also below Chelsea, and chiefly below Hungerford-market, little eels, "*Vibrio fluviatilis*," about $\frac{1}{30}$th of an inch long. The side of the vessel in which the water stands is covered with another precipitate quite distinct, not flocculent but hard, of a light brown, and chiefly towards that side of the vessel which is exposed to a moderate light. This precipitate is often mistaken for oxide of iron, which it strongly resembles, and to which it may probably owe its colour; but it may be known to differ from a simple oxide by the addition of muriatic acid, which gives it a beautiful green colour. When seen through the microscope, the colour will be found owing to the little dots of green which mark the polygastric character of these animalcules. These little creatures (chiefly I believe the "*Navicula fulva*") are covered with a crust of silica, and by boiling in muriatic acid the silica may be separated from the other portions which are soluble. In this way phosphoric acid, lime, and magnesia, may be separated with ease; and this will, I think, be found one of the best modes of collecting the phosphoric acid from water of this kind. The quantity of silica is very great, as the number of these little loricated animalcules prove. Life of this kind may at once be considered as a proof of the presence of all those elements essential to animal life generally, as these animalcules do not appear unless in the wreck of other animals or vegetables, whose requirements as to food are well known to be confined to certain elements. The abundance of silica is not from the upper part of the Thames, but no doubt from the sewers, proceeding from the decomposition of wheat, oats, &c., and may be viewed as a necessary consequence of the consumption of bread or any grasses used by cattle.

There is then a great deal of matter in a state capable of being converted into living forms; this matter is not in suspension merely, but in solution also. A large quantity of organic matter is precipitated in contact with clay and mud in the Thames, but a great deal is also in clear solution. This matter must be organized, of course, to some extent, and probably contains albumen; it seems to me that it is albumen which I have found in it, certainly a body much resembling it. The same may be obtained where many large animalcules appear; probably the quantity will be found the same whether the animalcules be formed or not. The clear solution becomes a mass of growth very soon, if the matter contained in it be organisable. Organic matter may exist in a state in which, even under favourable circumstances, animalcules are not formed, as I have found to be the case with some kept for some months in water. A similar thing may take place with the Thames water at London; if kept in close jars of earthenware, no change is produced in the organic matter; as soon as removed into glass bottles, a rapid change occurs, and a lively scene is produced of animals and vegetables. Kept in the dark, the water dissolves much organic matter, and becomes yellow; the water

Dr. Robert Angus Smith — over the living matter is clear, or, in other words, the dead matter is to some extent soluble in water; living matter is, of course, not capable of having its parts broken up by mere water, and is insoluble. This growing of plants and animals is, therefore, a good mode of cleansing water, when space and time are abundant, as in the larger operations of nature, but unfitted for waterworks, where neither are very ample. The mode of cleansing used by Water Companies is one employed by nature also, as all the water which falls on the soil is filtered by passing through; that is to say, it first becomes exceedingly impure, being filled with matter from the surface, and gives a part of this out again in passing through the soil. Water becomes hard very rapidly on the surface of some land, and it is strange how it adheres to its standard of hardness, remaining for a great part of the year the very same. A rapid shower, producing a sudden overflow of a ditch in a field, was found to be composed of water of 12 degrees of hardness and 16 grains of solid matter to a gallon; this same specimen also swarming with life.

I supposed, and others have done so also, that a shower would produce a stream of water softer than what slowly trickled through the ground; but on examining the water at Longendale in rainy weather it had actually risen 2 degrees. The Thames was also considerably softer in November, 1847, after some dry weather, than in February, 1848, after long rain. At Chelsea, in November, it was 13·44 degrees of hardness, taking 275 grains of soap test; in February, 14·94, taking 302 grains. It would appear that rainy weather softened the ground, and so made the matter more soluble, or the winter frosts broke up the ground and attained the same end. This latter reason is agreeable to the general opinion concerning the use of a frost, and the fact may also be taken as a corroboration of the opinion. The hard water will, of course, be better able to feed land with its soluble manures; or, if we choose to express it otherwise, the plants will more readily feed, finding the food more soluble.

However true it be that all soil filters water, it is no less true that any admixture of clay is detrimental. The clear streams are found in rocky countries, and, as was before mentioned, and well known generally, on barren land.

We have seen that the water of the Thames at London, is capable of decomposing with the disagreeable products alluded to, and when put in casks for sea-use we hear of a fermentation, with the formation of nauseous vapours, and of an inflammable gas. We have already seen that Priestley found inflammable gas from organic matter decomposing in water, and, in fact, it is a thing universally observed. Priestley said, however, what is not so much observed, that the air from the decomposition of a cabbage in the dark was inflammable, whereas, that in the sun produced very little inflammable air, and was not so offensive in smell. The fermentation of water may, in fact, be looked upon as a simple proof of great organic impurity. Organic matter will decompose either by going into inorganic gases, as in the dark, or into organized bodies of another description, if there be light to favour growth. These considerations bring us to the mode of storing water, and of supplying water to houses. If there be a large supply of water in a reservoir, it will, if impure, clear itself by vegetation, according to what we have seen by experiment, and as is seen in nature. In this case a reservoir must

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not be underground, but in the light; strong light and great warmth seem too much to assist chemical solution, the reservoirs should therefore not be so shallow as to allow this. However, there are probably few cases where water is to be so long stored; as to the usual cases, it may be said, that unless long storage is allowed, it is better that there should be as little as possible, unless the water is to be filtered before delivery. The reason of this is, that the course of purification of impure water is the worst state of all; even filtered water will not bear standing, because it also tends to purify itself still more by giving out in some form or other all its organic contents; and it is remarkable how the apparently purest water will deposit impure matter.

The same thing may be said of water stored on a smaller scale, as for private houses, there is no way of keeping it clear. If kept dark and cool, the change is retarded, and this is the best way for small quantities. It would be the best way for large quantities, also, if it were perfectly pure, as then no change whatever could occur.

But even when water is to be kept a day only, there is an objection to cisterns in most cases. If there be a little impurity deposited, the daily increase soon makes it a great impurity; and although the fact of the impurity remaining in the cistern be a sufficient proof that it has not been drunk or otherwise used, yet such a reservoir of impurity is constantly apt to be giving off some offensive matter. If the impurities be of the kind common in Thames water, and in the water of many of the Companies, or in the Manchester water, or that of some other towns, they are of a kind capable of producing animals very disgusting, and large enough to be seen sometimes by the naked eye. If even nothing but a green matter is perceptible, this is unpleasing in itself, besides never being alone, but inhabited by numerous little creatures visible with a microscope, although not so disgusting as those to be met with in the flocculent precipitate of the Thames water. Underground cisterns in London, when supplied with very pure water, contain in them some of the most disagreeable of these living forms; and although apparently a good method of keeping water cool, it is a plan to which the impossibility of cleaning is a great objection. Even stone cisterns, however clean stone in itself may be, are often filthy receptacles of water, for which not the stone but the water is to blame. If wood be used, pure water can never be obtained; and the enormous amount of crenic acid formed, with the peculiar smell of rotten wood, which happens even in new barrels, form great objections. The reddish flocculent matter is also not without inhabitants, for which it affords a good shelter.

If I come to the conclusion that water should either be kept in large quantities or kept constantly running, it may be said this was known to every one; true, but when this happens, it is the business of science to explain why it is so; and if this be not done, there are constantly found some who deny the general impression until a proof be obtained.

Dr. Clark, who has done so much towards giving the country in general an interest in the purification of water, advises also the alkalinity of the water to be taken at the same time as the hardness. I have found it more convenient to take the fixed contents in a gallon of water. By comparing this with the hardness, we find the excess of impurities not affecting the hardness. To do this, and take the alkalinity also, would probably be the best mode of treatment. In the springs at the source of the Thames,

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the fixed matter and the hardness are equal, or nearly so, whilst in the Thames at London, the fixed matter rises as high as 26 grains per gallon, whilst the hardness is 15 degrees. This gradual increase of salts not affecting the hardness, is a good indication of the rate of impurity in the progress of the river, and is a great cause of making it a less agreeable draught.

From experiments which I have made on the cause of vapidness in water, I am led to believe that the salts of alkalies are some of the most common agents. Dr. Clark has shown the great influence of temperature on the taste of water, but it seemed to me not enough to explain the frequency of the occurrence of tasteless water.

Water with carbonic acid in it did not taste vapid when raised slowly to 100° Fahr., the acidity being sufficient to prevent it, as I believe.

Lambeth water boiled and cooled could not be made to taste as well as water which had not the same amount of salts in it.

Pangbourne water, although excellent, when boiled down so as to saturate the salts which are not precipitated by boiling, tasted even when cooled excessively vapid.

Soda-water with alkaline salts, when boiled, is excessively disagreeable.

Twenty grains of common salt cause a gallon of water to taste vapid, and two grains and a-half of saltpetre or nitrate of potash have a still stronger effect.

The nitrate of lime in the water of towns mixed with the common salt gives an extremely nauseous taste to water, and causes it also to taste somewhat soft, although possessing such a large amount of matter as I have mentioned. Acids control this taste; carbonic acid, we have seen, prevents vapidness. A few drops of any acid render water pleasanter in a warm day. Acidity is strongly allied to coolness of the taste, as general experience shows. Acid drops and oranges in hot rooms are used for this reason, and vinegar also by travellers in hot climates. A few drops of any acid, vitriol, for example, are used by the workmen in chemical works to improve the water in warm weather.

Alkalies cause water to appear soft. Beer which is called hard is acid, and becomes soft by adding soda; this is common.

The salts of lime seem to be the only salts which do not easily render water disagreeable.

I may conclude this paper with a short summary of what I have said about water and air.

Summary.—1. That the pollution of air in crowded rooms is really owing to organic matter, not merely carbonic acid.

2. That this may be collected from the lungs or breath, and from crowded rooms indifferently.

3. That it is capable of decomposition, and becomes attached to bodies in an apartment, where it probably decomposes, especially when moisture assists it.

4. That this matter has a strong animal smell, first of perspiration, and when burnt, of compounds of protein, and that its power of supporting the life of animalcules, proves it to contain the usual elements of organized life.

5. Organic matter of dew contains less nitrogen.

6. The slightly alkaline state into which soil is put at certain periods

of the year, give it a facility for emitting vapours; whilst all vapours of water from organic matter contain organic matter. Dr. Robert Angus Smith

7. Water purifies itself from organic matter in various ways; by forming nitrates, as in sewers, and in the neighbourhood of cesspools and churchyards, under streets, in manured grounds, and other repositories of organic animal matter.

8. This may be done in a laboratory on a small scale, where animal matter, by means of a sand-filter, may be converted into nitric acid.

9. In the larger operations of nature the carbon also is oxidized.

10. Sulphuretted hydrogen is also oxidized on a small scale by a filter, being converted into sulphuric acid.

11. A filter, therefore, as an oxidizing agent, acts in proportion to its cubic contents.

12. Water falling on the surface of the ground gets rapidly saturated with organic matter; but in passing through the soil gets filtered, and the matter oxidized, making the porous soil and the air the great agents of purification in a country; whilst drainage will act by removing organic impurity as well as mere water.

13. All wells near houses, and all wells in towns contain nitrates, which may be easily traced to sewers or accumulations and outlets of refuse.

14. The alkaline salts of towns increase the vapidness of water. They abound in river-water, which receives the refuse of towns, and cannot be filtered out. The difference between the hardness of water and the amount of water per gallon gives a measure of impurity, as it indicates other than the lime salts, whilst the lime salts affect least the taste of the water.

15. A slight acidity removes vapidness, and produces a perception of coolness in the mouth.

16. Water can never stand long with advantage, unless on a very large scale, and should be used when collected, or as soon as filtered.

On the Surrey Water District. By Dr. Robert Angus Smith.

In compliance with directions from the Board of Health, I visited the proposed gathering grounds for water, which are situated in Surrey, stretching from Leith Hill on the south-east of Guildford, to Frensham, Farnham, and Alderholt Wood, on the west, at the distance of about 22 miles, and the grounds from Thursley to Bagshot on the north, including the district of Farnham and the drainage grounds of Fleet Pond, and many other small lakes, or ponds, as they are generally styled in the neighbourhood. In such an extensive district there are, of course, many streams to be examined, many springs and bodies of stagnant water, as well as the small lakes, which are constantly filling and emptying themselves, keeping up a fresh supply of water. All these sources and deposits of water received from me such attention as seemed necessary and compatible with the conditions of time and circumstance. As it was not my province to find out a new supply of water for London, but merely to examine a plan proposed, it was not necessary that I should be acquainted with all the water around, or that I should be

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able to say that there was no drainage ground so near London with an equally good supply.

As hard water was found to flow towards London from the north, the south, and the west, it was my belief, and probably the general belief, that there was no chance of any other supply whatever, and Pangbourne seemed the nearest place from which it might be taken out of the Thames with impunity. But as Professor Clark has shown that the objections to hard water are sufficient to deter any town from the use of it, the river water of the whole district seemed at once to be put out of the question, and either a new supply was to be sought after, as that of the Surrey district, or artificial means were to be used for rendering the river water soft. The state of the water inquiry seemed then to be fairly represented in the question: Is there any mode of obtaining naturally soft water for London, or must we use river water which has had the hardness removed by artificial means? That a place should have been found hitherto unthought of among all the plans for supplying London is itself sufficiently remarkable, and deserves the greatest consideration, as it at once obviates all the difficulties connected with the use of hard water, and connected with the means of artificially softening water. In examining the grounds, therefore, I have been fully impressed with the importance of the subject, and have endeavoured to give as simple a view of the matter as possible. I know that many analyses ought to have been given, and perhaps some persons would like a complete analysis of all the specimens, but this I have not had the opportunity of doing.

I think that in examining water the most important points are to know its general sensible qualities, next its hardness, then the amount of organic and inorganic matter, with an assurance that this matter contains nothing deleterious. It may be necessary to remark that rain falling on chalk dissolves it, and renders the water hard; or if it falls on the soil containing chalk or gypsum, the same result is obtained. If it flows over land containing much organic matter, a solution of that also takes place, and thus water is continually exposed to agencies which render it impure, or which render the use of it expensive. This latter, the formation of hard water, is the case in most if not in all the low lands of England, and there is often connected with it a considerable amount of organic impurity according to the drainage of the country. In the hilly parts of Wales and north of England the water is generally soft, and in some places more or less rendered impure by the organic matter of peat. The peaty matter on the hills of Lancashire varies from a few inches to a few feet in thickness; over a large portion of the district it is some feet thick. The silicious rocks give water of the purest kind, as the silica is very little soluble, and if there are any means at the same time of preventing the solution of organic matter, or of removing it when dissolved, water from the silicious rocks is the best that can be procured. The district proposed in Surrey is formed almost entirely of sand, shingle, and flints, forming a silicious stratum on which to collect the water. This stratum is covered in most places by a slight covering of peat. I went to the place first of all at the beginning of April 1850, the weather had been a little wet previously, but was fine for a part of the time, becoming wet for two days again, and again becoming

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fine, so that I had an opportunity of seeing the ground under various aspects.

As it is on account of the softness especially that a silicious district is preferred to a chalk one, I shall first put down the degrees of hardness of the Surrey grounds. It is a common opinion that soft water is entirely unfit for domestic purposes, except in the matter of washing, this arises from the habit of collecting rain water from the roofs of houses and elsewhere into barrels or very imperfect cisterns, where it is kept until wanted. Water of this kind generally goes by the name of soft water, as if it were the only soft water, whereas water of the greatest purity and brilliancy from the rocks will be found even softer, although, from its appearance, it would probably, by many persons, be considered hard. This common opinion is not surprising, as water which flows for a long time under ground or flows to great depths generally contracts hardness and brilliancy at the same time, and water from the chalk districts coming through such strata as remove the chalk thoroughly has a very remarkable brilliancy. Beauty and hardness have therefore become connected, and at the same time there has been a notion that softness and vapidness are intimate. Professor Clark has shown that these qualities stand in no relation to each other.

There is a district in Surrey with water from 2 to 3 degrees of hardness, and another with water about 6 degrees; there is besides that, the river Wey and also an occasional brook which rise to hardness.

	Degrees of Hardness.
Frimley, opposite Frimley House	2·7
Military College	1·8
Bagshot Village	2·25
Between Bagshot and Chobham Hill	1·5
Parallel with the road, Chobham-lane	3·6
Bourne Brook, near Bisley	5·4
Canal, south of Bisley	4·6
Bisley Brook	5·4
Henley Park	3·1
Mitchet Pool	5·6
Wharf Pond	5·1
Pirbright Brook	6·
Standward Farm	5·1
Fleet Pond	5·5
Aldershot Heath	1·
Beacon Point	2·7
Spring in the Farnborough-road	5·5
Cove Brook	3·7
Well, above Wrecklesham	4·8
Brook on Holt Common	2·3
Holt Pond	3·7
West of the Narrow	7·8
East of the Narrow	2·8
Wey at Kingsley	13·5
——— New Inn below Kingsley	9·3
——— Frensham	5·8
——— Farnham	14·6

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	Degrees of Hardness.
Wey at Tilford	6·7
Stream pond at Wishange Down	7·7
? Well at Frensham	7·3
? Stream at Fox	4·75
? Spring in the hill above Fox	9 3
? Stream in the Tilford and Farnham-road	5·75
Frensham Large Pond	5·45
——— Little Pond	8·5
Abbot's Pond	5·25
? Redhill Brook, Farnham Common	6·9
1st Redhill Green	7·3
2nd ———	8·7

Perhaps it would be satisfactory, as a means of comparing this with the northern supplies, to take some just as they occur in my note-book, so that any comparison may not rest merely on an opinion of mine.

Hardness of Waters in Lancashire, and part of Yorkshire, Derbyshire, and Cheshire.

	Degrees of Hardness.
Blackstone Edge, large reservoir, near the high road	1·5
Canal below Littleborough	1·8
Brook flowing to Walsden	0·61
Nearest reservoir on Blackstone	2·5
Longendale specimens	0·9
Comb's Reservoir	4·9
Todd's Brook Reservoir	2·4
Ashton Canal	9·7
Woodhead, above the tunnel	1·8
Etheran, at Hadfield	2·27
Spring in the rock at Glossop (Catholic chapel)	3·2
Peak Forest Canal at Whally	4·7
Whally Large Stream	3·7
Rossendale Brook, Macclesfield	3·5
Macclesfield Canal	7·66
Wash at Hockham Brook	1·3
Peak Forest Canal, at Bagworth	6·3
Todd's Brook Reservoir at another time	1·85
Comb's Reservoir	1·9
Feeder from Bosley Reservoir at the bridge	3·9
Shell Brook	2·8
Todd's Brook at the Gauge	2·2
Comb's Brook, the feeder	3·4
Tunnel water at Woodhead	7·5
Armfield	1·1
DARWEN WATERS:—	
Earnsdale Brook	3·
Jack's Key Reservoir	2·3
High Lumb Brook	1·5
Whitehall Brook	1·75

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	Degrees of Hardness.
Bayfold Brook	2·2
Halley's Brook	1·75
BOLTON:—	
Water at Nabs	1·36
Reservoir at Turton	2·27
Stream at Greenarms, Bolton-road	4·2
BURNLEY:—	
Hunston	3·7
Monkhall	1·25
Clough Croft	2·
Sweetwell	3·5
Swinden	8·
Thurs	2·7
Well at Meadows	12·
Water Company in 1846	6·5

These are the softer districts, of course in the low grounds the water rises to 8, 12, and 16 about Manchester and Liverpool.

A well at Rainhill was	23·
Stagnant water in the sandstone	8·
Drainage from cultivated land	12·5
Water at Sevenshulme	8·4
,, Stretford	15·5
,, ,, at another part	11·2

The variations then are very great in all large extents of country, and this variation may begin very suddenly. The only way seems to be to pick out a certain district having the desired qualities, and fix its boundary according to the limits of the geological formation. We see from the above table that there is exceedingly soft water on the drainage ground around the Military College, Sandhurst, on Chobham Ridge, on Hungary Hill and Beacon Point, on to Aldershot Heath, all the drainage ground of Covebrook, and most, if not all, of the drainage ground of Fleetpond, Leith Hill, and Hurtwood Common, and the district from Elstead to Godalming, whilst on all the rest of the district the average seems from 5 to 6 degrees, which may also be called soft water.

It might be well to inquire here what the cause of these degrees of hardness really is. Water falling on a pure sand can only take up silica; in all the instances, however, there is a certain quantity of lime found, however small in some cases. This lime comes from the sand, which therefore is not a pure silica, as indeed sand seldom is, but it contains very little lime.

I allowed water of 10 degrees of hardness to stand in contact with an excess of the lower sand of the Frensham district, that is, sand about a foot below the surface; after 24 hours it had risen only about a quarter of a degree of hardness.

At the same time water of the same kind was allowed to stand in contact with the white sand of the surface, containing within it peaty matter, and it rose in 24 hours to 6 degrees, higher by a quarter of a degree than the pond.

The water which is supplied to Farnham comes through the sand at

Dr. Robert Angus Smith — a depth of several feet, and is still soft and pure. Some of the finest water of the district was got at Beacon Point after passing through the sand to some depth and coming out as a spring, so that I am disposed to think that where there is hardness the nature of the surface merely, rather than of the sand generally, has a great deal to do with it.

This, then, is the great point in the district, that the water runs through sand, which can give it very little hardness in any portion of the district and in many parts only 1 to 2 degrees.

The total amount of inorganic matter contained in a gallon of the waters is as follows:—

	Grains.
Frensham Large Pond	7·25
Fleet Pond	9·12
Beacon Point Streams	2·76
Aldershot Heath	1·88
Cove Brook	6·08
Frensham Little Pond	8·88
Abbot's Pond	6·48
Henley Park	4·8
Frimley Brook	5·36
Mitchel Pond	5·72
Redhill Brook, Farnham Common	9·64
Rye Hill Common	2·96

Fleet Pond may be taken as a specimen of the water from one of the softest districts, which, however, in its flow, has become considerably harder than the springs on the hills, containing the same ingredients:—

	Grains.
Sulphate of lime	5.148
Carbonate of lime	1·80
Silica	·25
Sulphate of magnesia	1·43
Sulphate of potash	·094
Chloride of sodium	·132
	8·854

Also a little carbonate of soda, and a trace of iron scarcely perceptible to the taste. It is very probable that by evaporating larger quantities, and making a minute examination other salts would also have been found in minute quantities. In the Frensham Pond, there is in addition to the usual salts, such as sulphate of lime, carbonate of lime, and chloride of sodium, also chloride of calcium. It must be a matter of very little importance what is the nature of the salts when they are so low as 2 or 3 grains to a gallon.

A small amount of alkaline salts is a very important point in relation to the taste of water; in many parts the whole inorganic matter, both lime and alkaline salts, do not amount to more than between two and three grains, whilst the artesian well water contains above 60 grains. This causes the water at Trafalgar-square to taste exceedingly soft, or rather oily and mawkish, somewhat like soda water which has been boiled and lost all its gas, retaining the alkaline salts, which have a great power of rendering water vapid. The Thames water taken high up the river has also the advantage in an eminent degree of

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having few soluble salts, but if taken down the river the salts injure the water, however purified by filtration or precipitation. I believe this is a prominent reason why the Chelsea water, which is supplied to houses frequently very clear, is still to water drinkers by no means agreeable. It contains besides the salts which contribute to hardness, 8·5 grains per gallon of inorganic matter, whilst the pure water at the beginning of the Thames contains none whatever. At London Bridge there is an excess in the water of 17 grains per gallon not contributing to the hardness, but rendering it vapid, however much filtered and however brilliant in appearance.

The presence of iron in water is a great objection, I am not aware of any reasons for the objection to a small quantity, except those reasons derived from taste and sight. When it exists as it does in the state of protoxide dissolved by carbonic acid, the taste is such as to make it unpleasant. When this taste is removed by the precipitation of the iron in the form of peroxide, the colour is a sufficient objection, the water is brownish or it loses its brilliancy; if time is allowed a brown deposit is formed. The water of that portion of the district from Farborough to Chobham, has a distinct taste of iron, or of a combination of peat and iron, in some places one and in some the other. I had said to Dr. Playfair that I believed the district to be very limited where water was found having iron in it; I have since found, however, that a slight taste is also found in several parts of the grounds which must be attributed to the same cause. That at Bagshot is very distinct. The absolute quantity found is not great; the quantity in one brook where the taste seemed as strong as in any part was only 0·11 grains per gallon. To ascertain the taste of iron in water I tried a few experiments with sulphate of iron, and found that an amount equal to—

·16 grains of sulphate of iron in a gallon			=	·0414 of the protoxide could be tasted.
·32	,,	,,	,, =	·0828 of the protoxide was very distinct.
·64	,,	,,	,, =	·1656 of the protoxide was very disagreeable.

Lest there should be any difficulty as to the use of the palate as a test, I tried the same with sulphuret of ammonia, and was surprised at the similarity of the results, the colour being distinct at the same strength at which the taste became distinct. With ·0414 of the protoxide there is a scarcely perceptible brownness in the water; with ·0828 there is a more decided brownness; and with ·16 there is a brownness which may be seen without seeking any peculiar position of the light.

The water from Henley Park deposited ·144 of protoxide of iron in the state of peroxide of course; after this it was quite free from any peculiar taste, and was excellent water. This iron was not free; when sulphuret of ammonia acted on it, it was not instantly blackened. The amount of taste, therefore, was not equal to the solution of the same amount by itself, some iron being united with the vegetable matter. There was a good deal of peaty organic matter with it, both had fallen down together, and both are kept in suspension by the same cause.

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From whatever source this iron comes, and whatever be its disadvantages, which need not be underrated, they are removed by the proper filtrations.

In examining water one of the most important points to ascertain is the amount of organic matter contained in it. The quantity should not be perceptible to any of the senses, nor should it be susceptible of putrefaction or capable of forming animalcules. Organic matter, like inorganic, may be either in solution or out of solution, a very small quantity in suspension deprives the water of its brilliancy; it is often found in this state in the surface drainage of land. If the organic matter be in solution it is important to know first of all what kind of matter it is. The word organic has such an extensive range of signification that it really conveys to us no very real knowledge when applied in this way. Sugar or oxalic acid would both be treated as organic matter, but neither would cause putrefactive decomposition, or the formation of animalcules. Creasote, essential oils, and many other substances would be treated as organic matter whilst they are opposed to decomposition, and although they are not to be found in waters such as we speak of, there is still a substance not unlike them in its properties—the acid of peat, which is acknowledged to be antiseptic, and which does not resolve itself into living forms. Peaty matter is therefore not to be confounded with the highly organizable matter found in river water which has passed towns. Even far up the Thames, where the water is exceedingly brilliant, a green deposit will be found of minute vegetable and animal life. The organic matter of the Thames at London falls down after a time in the form of a very dirty brown slimy mass, with perhaps a little green in it. The first deposit seems enormous, and one feels surprised how it could have come from a bottle which at first appeared to have nothing in it but water somewhat muddy. If this water be filtered through paper so as to appear perfectly clean, and again bottled up, it soon makes another deposit not so filthy in appearance, greener, and more like vegetation; the sides of the vessel are also covered over with patches of animalcules, and the bottle becomes darkened. If it be filtered again, the action will still go on, until nearly all the organic matter is worked up, at least all the organizable.

I said in one paper that I had got what I believed to be albuminous matter, or at least proteine, in the Thames water, and Dr. Hassall has found animal fibre; this would at once account for the rapid formation of animalcules did we not know already that the organic matter of the Thames comes from a source which must render putrefaction exceedingly easy.

A solution of peat however, acid or alkaline, will keep, as far as I know, any length of time without alteration. There are varieties of peaty matter also of which it is unnecessary to speak; some deposit more green matter than others, but generally a very small quantity, and the peat itself cannot form animalcules. We may know indeed from the composition of the matter in water whether animalcules may be formed; they seem to have the same chemical composition as animals, live on the same nitrogenous substances, and are subject to very much the same laws. Spallanzani says, "Too much heat destroys animal life, and animalcula die about the same degree of heat (as leeches, worms, and tadpoles), 106°, 108°, or 111°.

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"All animalcula are not alike affected by cold. Some die at freezing, or a degree not much greater, others survive at 10 degrees. The odours and liquids that are a virulent poison to insects, are the same to animalcula. Such is the odour of camphor, the fumes of turpentine, sulphur, and tobacco; oleaginous, spirituous, and saline liquids are equally destructive. The electric spark is a thunderbolt to both. Agents slowly destructive of infusion animalcula are likewise fatal to insects, such as the vacuum of an air-pump."

As these great objections to Thames water are, in fact, like animals, and live on what other animals live, we shall get rid of them entirely by using water from a district where there is no food for them, or water which contains only peaty matter, which does not feed them. In saying this, I do not mean to say that there are no animalcules to be found in the district in question; I saw a pond on the heath with abundance, but the water which I have had has deposited as few as any water from any district can be expected to do. There is a kind of popular fallacy in connexion with animalcules, arising out of some notions once prevalent and now not entirely exploded, that there is no place without life in it, and that the elements themselves may be formed of active living points. But as far as good water is concerned, there is no necessity for any such theory; no microscope can see anything in it, and no one, not even a Brahmin, need be afraid that he is drinking living creatures. There ought to be none at all in our food or in our drink, and one of the most important things is to have water in which there is nothing liable to form them.

There seems to be no very satisfactory way of getting at the amount of organic matter when it is in very small quantities in water, at least a theoretical perfection is wanting in the process, but a practical perfection is easily attained by simply boiling down the water, drying the residue, and burning the result. The uniformity of results got in this way is such as cannot be surpassed. The quantity is too small generally to make it possible to make an organic analysis with oxide of copper in the ordinary way, and the result got in that way would be of no advantage to us. It is sufficient to get the quantity by burning off, and to get the quality by seeing the results after keeping it for a sufficient length of time. The peaty matter got in this way is the following:—

	Grains in a gallon.
Frensham Large Pond	·7
Fleet Pond	1·32
Wharf Pond	2·36
Beacon Point Springs	·76
Cove Brook	·36
Frensham Little Pond	1·76
Abbot's Pond	1·68
Henley Park	3·32
Frimley	2·24
Mitchel Pond	1·68
Redhill Brook, Farnham Common	2·86
Way at Frensham	2·44
Stream at Bagshot	6·20

Dr. Robert Angus Smith — I mentioned to Dr. Playfair that three grains was the highest; it appears that there is an exception here. It is clear, however, that there is very little. I may mention that all the waters have stood a sufficient time to form any deposit that might be likely to take place; some collected in warm weather in May and some in April.

As, I believe, these are the chief points about the water, the softness, the amount of matter in the water, the amount of organic matter, and the nature of the organic matter, it is only now necessary that I should speak of any difficulties rising out of any of these points. Muddiness or opacity of any kind will not require to be dealt with, the water seems all clear, indeed it is almost proverbial that water in sand is always clear. This is, no doubt, partly owing to the fact that water which is not clear would soon deposit so much of what it has in suspension as to cover the sand which forms the bed; if sand is seen clear at the bottom, and if it keeps clear constantly, it may be a proof rather that the water comes to it clear. If, however, water falls on sand, the particles are too heavy to allow of their being kept in suspension, and the water passes off clear. If it falls upon sand mixed with clay, or with fine particles liable to be kept in suspension, it soon washes them out, and the water on the free sand becomes again clear.

But the other reason that sand actually clears water is one which deserves the most attention, and all the filters in the country are a sufficient proof of the fact. If a stratum of soil through which water passes in a muddy state be put on a stratum of sand, and the water passed slowly through, the soil is not carried through the sand, but the water passes through perfectly clear. The water passing slowly through soil alone, at a sufficient depth, comes out of drains perfectly clear.

The Bagshot waters are known to contain iron to some extent, as Dr. Playfair has mentioned; but it is not always the case even with the surface water. Taking the whole extent of the district under examination, it is not common to taste iron. This metal can only be objected to when it is in a sufficient quantity to affect the taste. This occurs in what is properly called the Bagshot portion of the district. The iron cannot always be detected by the taste, because, I believe, it is united with a peaty acid, and the taste of both is in many cases very peculiar. The conjunction of the peat and the iron shows that the water obtains this taste at the surface, and that it is surface-water which tastes in this way. It is only in some places where there is any colour, the quantity being really very small, but as it can be tasted, it must of course be remedied if possible. If we follow any of these brooks downwards, we find that there is a continually brownish deposit going forwards, and the taste gradually disappears. The united peaty matter and iron are probably kept in solution by the same cause which keeps protoxide of iron in solution, and when the carbonic acid is dissipated, or when the iron becomes oxidized, the peroxide falls down. This is then a lesson as to the mode of purifying the water.

It has been said also that the sand absorbs a great deal of water, and that it afterwards comes out in various places according as it meets with impervious strata forming numerous ponds. If this be so, the ponds will consist of water which has come through a considerable extent of sand, of underdrain water in fact, and this will account for the

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water in these cases having less of any peculiar taste. I think it might be shown that wherever there is any taste of peat or of iron it is from surface-water.

The best proof of this will be found in the following instances. A stream at Redburn Green had a bad taste from the above causes, another stream running parallel, and about a hundred yards from it, was very pleasant to drink. This second one was traced up to springs issuing from the sand on the side of the hill.

At Beacon Point, the water which runs through the sand is not only pure in colour and taste, but also in softness. On Hungary Hill and the neighbourhood there are numerous instances, and it seems a general rule. On Chobham ridge also the water which has a colour and taste, is taken down to the sand, and issues again from a hill, where it is clear and pure. The under-drainage of the district is known therefore to give pure water, and as a supply for any town would, in all the cases seen by me, be very desirable.

The power of sand to purify water is really very great; I tried a few experiments upon it which I may as well mention. A strong alkaline solution of peat was made and passed through sand, the water came through clear, retaining only a taste of the earthy portion of the sand. The solution was strong enough to show colour through the twentieth part of an inch. Adding acetic acid to this ammoniacal solution until it becomes acid, gives an acid solution of peat; it is precipitated by some acids. This solution came through the sand equally clear. In both instances the matter was in perfect solution. As the action does not refer either to acids or alkalies, it seems probable that there is here an action independent of the ordinary chemical affinities, but as far as the purifying of water is concerned, it is enough to know that it is a fact. Pounded bricks acted equally well, also oxide of iron and oxide of manganese. Indeed every chemist must have perceived how beautifully some precipitates may be washed, and how pure the filtrate is which comes from them without any especial attention; amongst these oxide of iron and alumina are conspicuous, whilst others require many precautions, and several are entirely unmanageable, that is, they cannot be washed with pure water at all.

It would not be correct to say that sand is the most powerful filterer in proportion to its bulk, it is too coarse generally to act except when there are large quantities, and other substances purify the water, using much smaller quantities. It is however so general, and it is used in nature for purifying water so frequently, that it deserves most attention. The sand requires to be of considerable thickness, at least so that the water does not run too fast off, but at the same time nearly all the impurities removed will be found on the surface of the filter. In order to try the effects of filtration, I used strong sulphuric acid in which pieces of wood had been soaked, so that it was exceedingly black, thinking by the strength of the acid to overcome all action which a filter might have but the acid came through very pure, and left the upper part of the filter with a dark film, where all the colouring matter had been deposited. The same was tried with muriatic acid, which had been rendered impure by some vegetable matter, and which did not deposit by any amount of mere standing. The acid came through brilliant. The filtration of acid liquids in this way is an old process; it is given in an early edition of

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Percolation through a porous stratum is capable, in fact, of removing any amount of organic impurities from water, as the universal admiration of spring water sufficiently shows, and this removal of the organic matter which is an objection to surface-water, has generally been considered a sufficient compensation for the inorganic matter and hardness which it has acquired in the process, by going down to great depths and remaining a long time. It is true, that to remove the last traces of organic matter, seems to require that the percolation be continued a considerable length of time or space; it happens here as in other cases, that the purity is according to the extent of the process of purification.

It may seem, however, that the very word *crenic* acid is a proof that wells have organic matter in them of necessity; *crenic* implying that it has its source in wells, but they differ very much among themselves, from the impure well badly filtered, to the pure well with scarce a trace of organic matter to be found. There are cases in which organic matter comes from under the surface, but they are not legitimate exceptions. Sometimes there is a stream of water instead of a percolation, there are cases where vegetation has come up, and even fishes; many cases of bitumen and naphtha, which are also organic substances, not coming within the scope of our subject.

I shall describe the state of the heath as far as relates to natural means for purifying the water. The district is covered by sand or by shingle if it may so be called. This sand is of a reddish brown, and in some places has a considerable depth. On the surface is heath. The upper layer forming the soil of the heath is composed of peaty matter and sand; the peaty matter gives the blackness. When the peat is washed away, the sand is found to be of a pure white. In many cases where the plants have been removed, and the rain has begun to wash away the fine peat, leaving the white sand, the mixture of the two gives a peculiar colour to the ground, a grey with a tinge of purple in the distance. Sometimes the peat is found entirely removed, and then the sand or flints are found perfectly white, shining on the surface. The reddish sand lies immediately under it, and this effect has been produced merely by taking off a few inches, a mere scraping from the surface. The sand of the surface mixed with the peat is evidently washed white by the acid of the peat, and it is remarkable how decided this line of white and red is over the district. The soil is such a good filter that none of the acid goes much below the surface, so that there is no white sand to be found above a few inches deep, generally, as far as I saw, about eight inches; although there were cases where it was not so deep, and also cases where it was two feet deep. As the upper sand must retain water having matter in solution to cause this whiteness, so the under sand not being acted on, it must be penetrated by water having no such matter in solution. It follows that the peaty matter must get filtered out of the water before it passes from the upper layer to the under layer. It is then an interesting fact that at the junction there is a blackness, a black line in fact running along under the surface, having white sand above and red sand below, it is in fact the line of filtration. It is an old remark that humus acts as a charcoal filter;

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although its action here, except as a strainer, is difficult to understand, the soil does seem to be formed of a mixed charcoal and sand filter which does its work very effectively all over the district.

The sand above is found to be saturated with water, while the lower sand, not more than a couple of inches from it, is only damp; showing that the water passes through very slowly, and so has time to undergo the process of filtration, which is not a mere straining through a sieve, but an act of purification. The black line, which is an accumulation of carbonaceous matter, is a considerable hindrance to the passage of the water. This will perhaps account for the great part of the water in the streams, at least in the Bagshot district, being surface-water, as the water will have a greater facility for moving forward above the line of filtration. If the water in the ponds is in many cases water which has passed through the soil, and been thrown up by impervious formations, it will account for the greater freedom from a peaty taste, and also for a greater hardness than is found in the streams.

It might be asked if this filtering removes the iron, and the answer is already to be found in the wells and springs; if the iron is in combination, as I believe it is in most cases, with peaty matter, they will be removed together. At any rate they are both removed. Professor Way has removed many inorganic salts by clay and soil, and shown that they are absorbed by clay, especially in great abundance.

But to obtain these results, the water must be allowed to pass through the upper stratum, and thus the filter, instead of occupying only a few acres, straining the water from its grosser impurities, will be a thorough natural purifier, where the water will be elaborately cleansed by the ordinary natural processes which form the best spring-water. The water in that case will not be allowed to stand so long on the surface, and become impure in contact with the surface; this will prevent evaporation such as occurs in some parts of the district where there is stagnant water, it will also prevent the necessity of extensive artificial filtration, which the use of this natural filter will to a great extent, if not entirely, supersede. As to whether it will be in some measure lost in passing through the sand, this is a point which does not come under my experience. I wish to show, as I had occasion in a former paper to say, that when such impurities are to be removed, "soil is the largest natural disinfectant, and, in conjunction with air and water, is the most efficient of all, especially if the land be drained." And as soil removes organic matter from solutions, it removes also, at a certain depth, what the water has received in contact with the organic matter of the soil itself. If the processes at Hungary Hill, Leith Hill, &c., are copied, a great portion of the water when collected will be equal to what is obtained there at present; in which case a better product can scarcely be desired, and very few places can furnish an equal supply. It will, of course, be much superior to what Manchester is now receiving, and it will be equal to a great part of the district from which it will receive water.

It must be left to experiment to settle whether the turf should be pared, in order to improve the water, or if this would cause a loss of water. I do not know the quantity, but in many parts there is certainly a great lack of streams. If the water flows into the ponds by any under-ground channel, this lack of streams is a great advantage; if it is lost, it is a disadvantage, of course. As it appears from the quality of

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the streams, that the water is chiefly surface water, the lack of streams in some parts may be due to the rapid surface draining of the ground, which again becomes an advantage, increasing the facilities for collecting.

The great object, however, of going to this district, as far as I know, is to find soft water; the actual quantity of hard water could be supplied to London from several sources. The greatest hardness here is about six degrees; there is little water above that point. The application of artificial means to soften the water from hard-water rivers could not, I believe, bring it lower than this. We have then here prepared what would otherwise require artificial preparation if the water were taken from the Thames. The mode of purifying by lime, which is Professor Clark's process, has been tried frequently, and always with advantage, but then never in such enormous quantities as London will want. The lime removes the excess of lime in the water, where it exists as carbonate, and the organic matter also is taken down, leaving the water as clear as can be wished. Indeed, the water from lime districts is often remarkably clear; nothing can be wanted finer than the Thames at its sources as far as this quality is concerned. The wells of chalk districts are sometimes very strikingly superior to those of the neighbouring districts, and possess a brilliancy not easily attained otherwise. It is astonishing what an amount of matter of every kind is removed by the lime; the fine particles which cannot be seen, but only cause a dulness in water, are rapidly dragged down with it, and stray vegetation, animalcules, and filaments of various kinds, are rapidly made to sink.

Professor Clark has shown that there is very little, if any, excess of carbonic acid in river-water, and that the water would therefore not lose any of its carbonated nature by his process. There is an excess, however, of carbonic acid in well-water, and sometimes to a considerable extent. The same will probably be the case in water well filtered through a sandy soil, which will in fact be well-water, or, as we may call it, artificial spring water. This term was used by Marshall to designate rain-water which had been passed through a bed of sand, and made more palatable—a mode which he recommended to farmers as valuable for cattle, being both agreeable to the taste, and more wholesome than hard waters. There will be an advantage in favour of the natural process without the lime.

As far as air is concerned, river-water will probably contain much the same quantity, or at least not less after liming than before. A quantity was tried, by raising the temperature of the water slowly, until bubbles of air appeared on the sides of the vessel and bulb of the thermometer; these were generally very distinct at about 70° in both specimens. A very good mode of very readily trying the aeration of water, as far as oxygen is concerned, is the use of sulphate of the protoxide of iron. This salt oxidizes very rapidly, and leaves a deposit of peroxide of iron in a yellowish state. If water is boiled previously it does not oxidize, but remains perfectly clear. A little practice with this mode of testing will give a very clear idea of the amount of oxidation of water. If the weight is required accurately, it is, of course, subject to an error. When water is thoroughly deprived of its oxygen in this way, protoxide of iron may be precipitated in it of a pure white; this protoxide, if put

at the bottom of a vessel of water deprived of oxygen, will show how rapidly the water absorbs it. In 10 minutes a change will be found to take place.

However valuable the process of Dr. Clark may be, all will allow that, if it can be left out without loss, it will be an advantage to do so. The advantage of using a natural supply, instead of one requiring preparation, must always be great; the labour of the manufacture, and the risk of mistakes, being reasons enough. I have no wish to speak against Professor Clark's process, having seen several remarkable instances of its value. I must be excused, however, for preferring simplicity when it can be got. This and some other questions might readily be answered by experiments which private individuals cannot make.

For the same reason, it will be important that water should be put into reservoirs in a state of purity, and it will not require any after-purification, or at least very little. Water which is perfectly pure cannot corrupt. The water which does cause the growth of great numbers of animalcules and much vegetation cannot be in a pure state, and the formation of these bodies is a removal of the evil by making the impure matter insoluble. Well-water or spring-water, passed through inorganic strata for a sufficient length to destroy the organic matter does not trouble us by growths of any kind; river-water, coming over the surface of the ground, does, however, often cause immense masses of vegetation. The same clearness is preserved when water has peaty matter only in it. There is no vegetation, or very little. Sometimes the stones remain clear for years; there are cases, however, of green matter forming, probably when the peat is mixed with other vegetation, which affords materials for the growth of new forms. Water bubbling from underground may be kept in the dark in a stoppered bottle without change; but river-water, or water having organizable matter in it, will not keep so. It will form vegetation first, at least in the light, and afterwards, if the same vegetation be kept in it, it becomes putrid, dissolves to some extent in the water, and becomes very nauseous both to the taste and smell. If it is kept in the dark, it becomes putrid also, without the formation of the vegetation previously. This is the result of keeping waters in bottles; it will not perhaps be possible to apply all this to reservoirs, as the quantity will be great, and the change frequent. If impure water is put into a dark reservoir, it would, no doubt, be retarded in its deposit either of living or dead matter, and the deposit would be probably longer in forming than in a vessel kept in a house. A dark reservoir would therefore be of advantage in preventing any impurity in the water from coming to light in the form of vegetation, of animalcules, or black slimy deposit.

The question might then be asked, what would be the result of keeping pure water in an open reservoir, or water as free from organic matter as that of which we speak? The answer would be best got from the ponds themselves; and there, in such cases as those where the water cannot reach the pond without passing through much soil, the water lies on the cleanest sand, as at Frensham. I do not see why the water may not all be so managed; but, at any rate, the amount of impurity got from the atmosphere, except in the neighbourhood of a town, cannot be more than the passage of the water through a filter before delivery could abundantly clean.

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What I wish more particularly to say is, that the presence of life is not the only index of the impurity of water, although it is an important one; and that it is not enough to prevent any living creatures from appearing, by using dark chambers and a low temperature; that the water must not have in it the matter capable of forming these creatures, and then the place is not so much a matter of consequence; all that is wanted is, that there be no source of impurity which can reach it.

We are not surprised that water from ploughed land, pure as far as clearness goes, but containing four grains of organic matter to the gallon, which matter, when burned, has a strong nitrogenous smell, should, in the course of six months, form a deposit in a reservoir of considerable thickness; and, on the other side, it can give us no surprise when a reservoir, having only peaty water in it from the Bolton or Pike district, should have no appearance in it whatever of vegetation. In one there is the material, and in the other it is wanting. The mode of keeping water pure in dark places is applicable, therefore, to all water which has organic matter in solution, but not essential to pure water: it is, in fact, a mode of preventing the impurity from taking a nauseous form, and also of getting into a more deleterious state.

From the manner in which I find this paper has been written, it will be better that I should give a short abstract of what I believe true on the subject.

The Surrey district is composed of sand and shingle, with a thin covering of heath.

The water from it is soft, varying from 1 degree to 6 degrees, the average being probably about 4 degrees of hardness.

The nature of the surface renders it exceedingly fitted for natural filtering or purification by drainage through the substratum. This is the mode in which the purest waters are obtained, and by which the purest waters are got from peaty districts.

This mode of slow filtering removes all organic matter from solution, so that the organic matter on the surface is a matter of less importance, as it is remedied by drainage.

This is the method by which spring-water is prepared, and by which it is aerated, or supplied with carbonic acid and oxygen.

This water might be supplied to towns without filtering, unless by some unforeseen circumstances it might be somewhat diminished in brilliancy during its flow.

This has an advantage over the river-water in softness and in absence of organic matter, which qualities must be produced by artificial means when river-water is used. The comparison in expense and practicability must be a matter for further investigation.

This mode of filtering removes iron in the state in which it is found in parts of the district.

As far as surface is concerned, the district in Surrey is peculiarly fitted for this mode of purifying water.

Water so purified could become nowhere putrid, from want of the material which putrefies. Peaty matter itself does not putrefy; even if it were not removed, there would be very little organizable matter, much less than in the neighbouring rivers.

Reservoirs with water thoroughly purified would not become filled with vegetation in the light or in the dark. To prevent water from

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putrefying, presupposes putrid matter. Water should not be supplied with such matter in it.

As little rain as possible ought to fall into reservoirs, unless, perhaps, many miles from towns, the impurity in the rain even outside of towns being great.

It may be objected that water so pure as this cannot be got; and this brings us to another reason, the reason which seems to me most in favour of covered reservoirs arising from the impurity of rain got from the neighbourhood of towns. This impurity must be very great near London, and probably several miles from London. I have just been collecting water from the fields a mile from Manchester, and about two miles from any large chimney; it is very impure, and of a bad taste; it could not be used as a supply for a town without careful filtration. I reserve the description for another occasion. It would be an important thing to know at what distance from London it would be safe to leave reservoirs uncovered, and whether at any distance whatever a large amount of rain-water would be an injury. It would probably be refining too much to speak of any injury to distant reservoirs from rain; but as to supply reservoirs in the neighbourhood of the town, it would not at all be an over refining, as the amount of impurity is very decided. If the water could be got so pure as not to require filtering, then reservoirs at the town would not be wanted, or at least diminished to a very small size. If it should be found that filtering cannot be dispensed with, the removal of filters far into the country will, I believe, be an improvement, as in that case they will get the water in a clearer state, and have less duty imposed upon them.

Plan of Drainage.

I believe I have given as far as I have gone a correct account of the water district, the observation of drainage in many cases of this and other districts has suggested to me a few remarks which may be added, although perhaps not in conformity with the general scheme, the details of which I do not know. I believe it is essential to the district that it be drained, if possible, in every part of it, with more or less care. It is perhaps too much to expect that this will render the use of filters unnecessary but it is not too much to expect that fewer would be wanted, as a little straining would probably be all that would be wanted at certain times. The water might be collected in the same way that water is now collected by streams and rivers. The mountain streams seldom bring down any mud, but are generally clear. These streams are purified by natural filtration, sometimes from great impurities. The water at the top of a hill may be quite brown, but this is no indication of the colour of the same water at the bottom of the hill. The water on the top is brown very frequently from lying for a long time on the moss or heath, having at the same time a strong taste, quite unpalatable. When this goes a few hundred feet or yards down, it is clear and beautiful, having no taste. The manner in which this is performed is curious; it has often surprised persons, and I had an opportunity, a short time ago, of finding some water brown from its source in the peat, in the act of filtration. The

Dr. Robert Angus Smith. water passed under the surface; he side of the hill on the upper part was wet, so that the feet sunk some depth in the moist soil, but although the water was flowing down the hill, the surface became dry and solid; the water, therefore, sunk down. On going further down the hill, the water came out again, so that the ground was wet. It flowed to some distance, and become lost afterwards in a gravelly part of the ground. Again the soil was dry, the water passed under, and emerged from the surface a few yards below, forming a well, which served for cattle. From this well it ran down into the stream at the bottom of the valley. In the course of an hour's walk on the Derbyshire hills, I met several cases where the stream entirely disappeared from its channel and came out below, pure. Cases not so distinct, that is, requiring more examination to trace them, are in abundance. Heath, then, may cause any amount of impurity in water: it is a matter of no consequence if there be only a purifying agent below. Water does not run over the surface merely when the ground is sufficiently porous. In this case the substratum was a white rock, broken into gravel and sand on the surface, and varying in its porosity from the manner probably in which it was broken. The manner in which the water ought to be collected from land, ought, in my opinion, to be similar to this. The arrangement of the surface might be made in such a way that the water could not flow from the hills without passing through a good deal of the lower strata. For example, if a ridge of gravel and sand were run along the side of a hill, the water would pass through that before it came to its outfall. In doing this it would be purified. In the same way also it might be necessary to prevent the water from flowing over the brink into streams before passing throught its purifier. Wherever the water does undergo this process to a small extent, a little assistance would probably complete the effect. The water would be purified on the spot. Some hills resemble closely barrels of water; they are tapped below, and the water comes out, whilst the surface does not betray a great amount of water.

Any one may have observed that a mossy hill seems always wet, but it is a most difficult thing frequently to get any water from it. The water does not become perceptible till near the bottom of the hill, when it oozes out of subsurface cavities, or through peat, gravel, or sand, as it may happen to be. If it happens to come through the peat only, it will, in most cases, be more or less brown, but if it happens to go deeper it will be purified. In cases where it will not be sufficiently deep for purification, it may only be necessary to deepen the stream, and so prevent any water from coming into it, except from a great depth. This mode of flowing may be seen in the draining of mosses, where water is collected six feet or more under the surface, where it does not flow at all over the surface, but passes down immediately, and is collected below, so that it is possible to cause the water to pass through any required depth.

A great deal of the water of the district passes already through this ordeal, and becomes purer accordingly as it does so. The consequence of this is, in some places, that it gets harder, as around Wharf Pond and some others, but it is not always the consequence, as the deep springs in the hills show, and the water of Farnham.

I am not sufficiently acquainted with the geology and levelling of the district to know how this could in all places be done.

Dr. Angus Smith examined.

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1. You have examined the waters of most of the gathering grounds for the improved supplies of the Lancashire towns, have you not?—Yes; I was engaged for the examination of the Manchester new supplies, derived from gathering grounds, on the hills between Lancashire and Yorkshire; and also the proposed gathering grounds from hills to the north of Derbyshire, and some from Cheshire. I examined the gathering grounds for the supply of Bolton, and part of the gathering ground appropriated for the new supply of Liverpool, and also those for the supply of Burnley and other towns in Lancashire.

2. In those instances, the proposed gathering grounds were wastes and moors, were they not?—Always so.

3. Did you examine the supply proposed by Mr. Rawlinson to be brought in for Liverpool from the Bala Lake in North Wales?—Yes, I did.

4. In all these cases you went to the grounds yourself, and collected for yourself the specimens for analysis?—Yes, I did. I may observe that besides the grounds mentioned, I have examined the water from grounds in other districts, simply to determine some questions for myself, as to the effect of peat upon waters.

5. You completed practical analyses in the several cases for advising on improved supplies for the use of the population of the several towns?—Yes, I did.

6. We understand you to concur generally in the conclusions from evidence we have received, and which you have seen as to the superiority of soft water over hard for drinking, for culinary purposes, for washing, and for manufactures?—Yes, I do. The most earnest attention has been directed in Lancashire, however, to the importance of soft water for manufactures. The number of schemes which have been proposed for removing lime from boilers, or for removing it from the water, show the importance that manufacturers have attached to the subject.

7. You have now visited a number of waste lands, heaths, and moors in Surrey and Hampshire, which have been pointed out to your consideration as eligible gathering grounds for improved supplies of water for the metropolis, and have examined specimens of water from them?—Yes, I have been over these grounds nearly a fortnight, and I have examined about eighty specimens of the water. For two days I was accompanied by Professor Way.

8. Before entering into the particulars of your examination, will you state the character of the waters obtained, as compared with the water derived from other gathering grounds which you have examined; and, first, as to the Bala Lake; have you the analysis of that water?—Yes; it is the following:—

From the Dee at Llangollen.

Hardness	2·5
Carbonate of lime	2·1
Alkaline salts	·532
Salts left by the decomposition of the organic matter	·168
Organic matter	·28
Entirely peaty matter	

I had too little water for further particulars.

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9. You have examined the water as supplied to the town of Farnham?—Yes, I have.

10. Will not the Farnham water represent a fair specimen of the water derivable from a large extent of the proposed gathering grounds?—Yes, allowing the average of the Farnham water to be about two and a-half degrees, it will represent the quality of the water derivable from the whole of the eastern part, that is from 20 to 30 square miles of gathering ground, as far as I have seen, nearly all waste.

11. Will you give in the analysis which you have made of this water?—The specimen of Farnham water which I received was unfortunately taken from a place where impure matter from a garden was allowed to enter; I shall therefore give the analysis made by Professor Way—

	Grains in a gallon.
Silica	·55
Lime (as silicate?)	·375
Sulphate of lime	·280
Sulphate of magnesia	·557
Chloride of magnesium	·552
Chloride of sodium	1·440
Chloride of potassium	·354
Organic matter and water of combination	1·245
	5·323

So far I can corroborate this, that I found a spring on the same hill containing 2·76 grains of inorganic matter in a gallon, and ·76 of organic.

12. From the guagings taken at the end of six weeks' rain-fall, it is reported to us that the extent of supply derivable from these wastes which are distinguishable from the rest would be about 28 millions per diem, or equal to a daily supply of 100 gallons per house in the metropolis; will you state the general character of this water as compared with that of the Bala Lake?—I cannot speak to the quantities; but in respect to quality, the Farnham water is equal to the mass of any Lancashire or Cheshire water derived from gathering grounds which I have examined. In softness it is equal, in some places superior to the Bala-Lake water, from the proposed collecting point above Llangollen; it is also less coloured with peat than the water of that lake. There are portions of water derived from what is called the rough rock in Lancashire, nearly as perfect in every respect as distilled water; but the gross amount of the Farnham water would be equal to any other gross amount of soft-water supply for a time which I have examined, taken indiscriminately.

13. We are now speaking of the water as at present derived; but may it not be even further improved by care in its derivation or collection?—Yes, materially.

14. In what way?—By under drainage chiefly.

15. Will you describe the advantages you expect from under or shallow drainage?—My view is that most rain-waters will be improved by passing through an appropriate filter. My belief is that all water coming from rocks or sand is more brilliant than simple rain-water. All rain-water is apt to bring down with it vegetable or animal matter floating in the atmosphere.

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16. Where have you made collections of rain-water?—In Manchester and the neighbourhood of Manchester.

17. Then you probably give us an impression simply, and not the results of experience, as to rain-water falling in purely rural districts? —Yes, that is so; but still I should prefer the water which had passed through a filter, as purifying itself from the matter caught upon the surface, for some foreign matters are caught upon the surface of all gathering grounds which have yet been found, or are likely to be found, for town supplies.

18. Are you aware whether in any of the towns now supplied, or to be supplied, with soft water from gathering grounds, as at Bolton or Manchester, under drainage has yet been thought of?—No, none of them.

19. Even if the surface water were taken, as for the northern towns, from the surface of the district, crudely as at present, and without any further improvement, would not the general supply from the entire district you have examined be superior to most river-waters, not to speak of the Thames?—Yes, certainly. It would have the greatest superiority in respect to softness; it would have less mineral, and would be nearly pure from animal matter; and it would have less vegetable matter. The only matter in it is peat, and that is not visible to the eye. I except some portions of the district which might be separated or improved.

20. The whole district is supposed to be covered with sand; if so, what portion is covered with the same description of sand?—Speaking roughly, I saw 20 miles of land, and 30 miles of shingle and sand.

21. What are the chief causes of the variations in the quality of water which you find in this district?—Variations arising from peat chiefly.

22. Is not the peat very thinly spread over the whole district?—It is not thick anywhere; but the variations in the quality of the water are caused by the state and inclination of the surface, which occasions the rain to wash the peat surface alone before it is discharged into the brooks.

23. We understand, then, that by the shallow drainage which you contemplate, you have in view the instance of the derivation of the water for the supply of the town of Farnham, by which the water falling on the surface of peat, passes through the peat, and thence through the sand into the tile-drain, cleared of the peaty infusion?—Yes, that describes the process.

24. What is the depth of the peat on the gathering grounds for Manchester?—Some of it about six feet deep; a great part of it about four feet deep.

25. What was the depth of the peat on the gathering grounds for the new supply of water for Liverpool?—That which I saw was from two to three feet deep.

26. Mr. Donaldson, the agricultural surveyor, reports to the Board, that the surface peat on the Surrey wastes is so thin, much of it some six or eight inches thick, that it might be taken off at a cheap rate?—Yes; but from the instances which I observed, it would suffice to take off two or three inches of peat from the surface.

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27. You do not then think that the infusion of peat, even if the water were taken as it is, would be highly objectionable?—No, it is not thought so; peat itself is highly antiseptic; it is not considered favourable to the production of animalcules; it is not directly convertible into animal life like the organic matter in the Thames, and most river water. The only objections I know to it are the taste and the colour, which are disagreeable when the infusion is considerable.

28. Besides the instance of shallow drainage in this particular district, have you observed shallow-drainage waters in other districts? —Yes, in a few instances. I may mention one at Rochdale, where the surrounding waters went as high as 13 degrees of hardness; but the shallow-drainage water obtained from a ploughed field was about four degrees and a half. The comparative purity of the drainage water in other points was similar.

29. Will you state your own view of the powers of the surface stratum of land for depuration?—I passed a strong solution of peat through a filter of sand, and found it quite purified. I passed then an ammoniacal solution through the filter, such as is found in warm weather on the tops of hills on peat, and found it quite clear. Then an acid solution was passed through, which also was quite purified. Afterwards, I passed the same solution of peat as at first through various materials; oxide of iron, manganese, lime, and iron filings; all of which substances purified the peat. I then passed strong solutions of woody matter in mineral acids; these also became pure; sulphuric acid and muriatic acid, for example. The matter was left chiefly on the surface of the filter. I observed also that all the peaty districts have a black stratum a few inches deep, below which there seems to be no organic matter, or very little. A similar stratum, not coloured, may be observed on all soils, but rather deeper. Water taken above the point of filtration, that is, not having passed below this stratum, contains much organic matter; but below this line it is true drainage water, and is purified like water from a shallow spring. Leaving the cause for examination elsewhere, these facts lead to the conclusion that the power of filtration to remove colouring organic matter in solution is really enormous; but it must have time, as the action is not a mere straining through a sieve; the artificial filter is for this reason generally too small for the full effect obtained by the natural mode of filtration, where time is given for a complete act of purification.

30. Will you describe the general condition of the other remaining districts?—The Frensham district is entirely a loose sand, with very little peat, the water less soft by three degrees than the northern and eastern portions; but I think it might be had still softer if the district were drained faster—an experiment which I made showing me that what little lime it did dissolve was, in a great measure, if not entirely, caused on the surface. The districts of Hurtwood and Leithhill are covered with gorse, heath, and wood; and the water will, I believe, be found very soft under any mode of collection—that is, whether drained or not. I have founded my opinion of the water independently of the Bagshot eastern district, the water from which, as it at present flows, is too much coloured by peat, and so much so as to be disagreeable to the taste. I saw abundant reason to think, however, that by careful filtering in

its natural position it would be completely purified, and would then make a valuable gathering ground. In company with Professor Way I saw instances of purification in this manner, I have therefore only to speak of its capabilities as a gathering ground, but not of its present supply of water. Dr. Robert Angus Smith

31. Do you see your way of obtaining any supplies of equal purity for the metropolis?—I know of no other silicious district near London, and I take it for granted that there is none producing soft water, or geologists would have pointed it out. Any other natural soft supply, therefore, seems entirely beyond all expectation, and the only mode of obtaining any other supply of soft water would seem to be by artificial purification. As the process of purification could not by any means yet adopted bring it to a point softer than the district proposed, I see no inducement to try any hard-water supply, and to be at the trouble of artificially softening it; whilst, I may add, that the artificially softened water does not equal the natural supply, it is less aerated, and may be otherwise objected to.

32. Even if little or nothing were done either on the surface or with the mode of collection, we are to understand, then, that the supplies derivable from the greater portion of these Surrey sandy districts would be on an equality with the soft water supplies of the northern towns you know of, as at present, collected and distributed to them?—Yes, certainly.

Dr. Angus Smith on Water-pipes.

The use of iron seems essential for the conveyance of large bodies of water, the use of other materials may be better suited for smaller bodies. It is the most wholesome that can be used, although it has several disadvantages connected with it, arising from its tendency to oxidize on exposure to water having air in it. There is seldom carbonic acid in town waters sufficient to dissolve the iron, and to make a chalybeate strong enough to taste. The amount of oxygen is greater than the carbonic acid, and to some extent always present, so that the peroxide is found in the water and not the protoxide. As the peroxide is not soluble in water, it forms a milky or turbid fluid which is more or less unpalatable. This turbid state may exist to a very small extent so as merely to take away the brilliancy; even then, however, it is an objection as it affects the appearance and the palate. For this reason pipe-water when apparently very pure will precipitate on standing yellowish flocculent matter. Perhaps it would not be right to say that the water has any taste when in this state, but it is certainly inferior in some respect, less pleasing to the palate. Pipes which are well supplied with oxygen by filling and emptying with water are more apt to oxidize according to experience, and this we might readily expect. This must be known to all who have attended to the state of the water after the pipes had been for some time empty. But the oxidation goes on at all times, as may be seen by putting a little protoxide of iron into the bottom of a glass of water, in a short time it is quite oxidized or

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of a light brown. A piece of iron may also be observed to rust in the same way. It becomes a great nuisance if it comes out of the pipes in great quantities; however, it is probable that no water can be brought through iron pipes without losing some of its purity. The water will wash it away when formed, but if the flow be constant very little will appear at a time; the great safeguard therefore will be found in using a large amount of water.

Hard water seems to be a great preservative of the pipes by incrusting them with lime; it becomes, however, important to know how to preserve them when soft water is used. Whatever is put on iron is after a time removed, no matter how thoroughly the contact be made. It has been proposed to use tinned pipes, made of wrought iron. The covering of tin is in contact with the iron, but even this is not enough, and one is almost inclined to think that the only method of keeping the iron clean is that which engine-men employ—constant rubbing and abundance of oil. It shows us how very insinuating the air is, how it goes into pores of which we could not know the existence, and when it once penetrates under the surface it tunnels onwards in a surprising manner. When iron is covered with tin the two metals unite and form an alloy some depth into the substance of the iron, this alloy gradually decreases in its amount of iron until at the surface there is a covering of pure tin. One would suppose that through this covering no air could possibly go. It does get through, however, not merely from mechanical lesion in the tin, but from the imperfection of the surface and the method of covering. Holes are left excessively minute, but sufficient after a long time to make themselves perceptible by an accumulation of oxide of iron, which they dig out and raise up like mole-hills on the tin plate. The smallest hole will be enough, and it must be a small hole indeed which will not allow the passage of an atom of oxygen. The oxide rises up as it seeks more room than the iron. It is also porous, and becomes in fact an inlet to the metal which is underneath it. As more comes up the hole gets larger, the oxide breaks the tin up in various places, and completely envelopes it in rust. I am not aware that there is any reason to attribute this to galvanic action, which may more properly be supposed to preserve the iron, tin being positive to iron in cold weak sulphuric acid. A similar action goes on even faster with many coverings where there can be no galvanic action. Enamelled surfaces have not, I suppose, been tried for large pipes. I proposed a mode of covering with pitch for the Manchester pipes, which seems to be useful, although there is room enough for invention still. It covers them with a black varnish, which is also a great preservative to the outside of the pipe if the covering is well made. The outside is exposed to drainage, and the pipe is very liable to become entirely wasted away by this action, leaving only its form in the shape of a piece of graphite. It is, in fact, common to find iron exposed to under-drainage, dissolved out in this manner, not breaking off in scales and becoming a mass of rust, but being removed completely, leaving its form only. A piece which Mr. Binney gave me from a colliery near Manchester, consisted of iron 38·8, silica 19·7, carbon 40, and a little oxide of iron. Water-pipes are subject to the same decay when not protected.

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20 grains of cast-iron borings were added to 20 ozs. of water, and allowed to stand 24 hours.

	Oxide of Iron.
1st deep well water, with much carbonic acid .	·15 grains.
Distilled water	·08 ,,
Water with a little common salt so as to taste	·16 ,,
Manchester pipe water	·13 ,,
Water from sewers	·13 ,,

The water with many salts in it acts most, the purest water least, because there was little carbonic acid or air in the distilled water used here. The oxide was not in solution, and gave little taste to the water. Iron suffers in contact with air, carbonic acid, and soluble salts in water, so that whether it be in contact with water from well-drained land, or badly-drained land, it is still in danger.

The use of lead pipes is common enough; and although the danger from lead has often been pointed out, there is no diminution in the amount used. It is acknowledged that with soft water lead is very dangerous, but I am disposed to think that it is dangerous even with hard, except when a crust forms upon it. When a lead pump is used, no matter how hard the water is, there is still lead to be found in it. In one case I found lead where there were 62 grains of lime salts in a gallon; the family filtered the water, but that did not quite remove it, although it was much improved. This shows the lead to have been in complete solution, although the water was hard. The pump was made of lead, so that there was a constant friction preserving the surface clean and assisting comminution.

In another case where there was a lead pump and well, the water also coming from a badly-drained and putrid underground, the water was acid, and an acid salt of lead was found in the water, strong enough to have a distinct taste of lead, and otherwise nauseous from the other salts, such as nitrates and chlorides. A few bubbles of sulphuretted hydrogen made the whole of a deep brown instantly, and it was lamentable to find that the persons who used it did not suspect any evil from this source.

The use of zinc in lead pipes has been proposed as a remedy, but it is not desirable to drink even zinc. There is a lead pipe made in Manchester covered with tin, a very thin film of it protects it considerably from the action of water acidulated with acetic acid. Probably for water-pipes it may be very useful. It is time that some change should be made in the small water-pipes now made of lead, and that the use of lead pumps and cisterns should be done away with, unless they can be protected.

Dr. Angus Smith on the Coating of Water-pipes.

The mode of coating water-pipes, which I proposed for the Manchester water-works, and which they have adopted, was the following; —The pipe is made clean, free from all rust and earth which clings to it on coming from the mould; the cleaning is a very important thing, as the success very much depends upon it. The surface is then oiled with linseed oil, in order to preserve it until it is ready to be dipped.

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When the coating is to be made, the pipe is heated in an oven to about 300°, which should also be measured in such a manner as to prevent soot from coming on it. It is then dipped into a pan of gas pitch, and kept in it for a short time until it shall have taken up the pitch as intimately as is possible. The pitch should not be too hard, so hard as to be brittle, nor should it be too soft, so as to adhere to anything; when it becomes too hard it may be softened by adding more oil.

When the pipe is taken out it is covered over with a fine black varnish, and looks exceedingly well. How long they will last is not easy to say; but if well done they will last longer than any other mode I have seen. I was at one time not inclined to think it of much value, but I saw lately one which had stood out every season, and was still in very good order. I am disposed, therefore, to think that it might be made to endure as long as can reasonably be wished.

The surface of iron is exceedingly difficult to keep clean, and, probably, no plan has ever quite succeeded but that which the engine men employ to keep their machinery bright, that is, abundance of oil and constant scouring. This oxidation shows us how very insinuating the air must be; it goes into pores of which we could not know the existence, and when it once penetrates under the surface it travels onwards in a surprising manner. When iron is covered with tin, the two metals unite and form an alloy some depth into the substance of the iron. This alloy gradually decreases in tin, until at the surface there is a covering of the latter metal alone. One would suppose that no air could go through this covering. It does get through, however, not, I believe, from any mechanical lesion of the surface, but from the imperfection of the mode of tinning. Holes are left excessively minute, but sufficient after a long period to make themselves perceptible by an accumulation of oxide of iron, which they throw out, and raise up like mole-hills on the tin plate. The smallest hole will be enough to begin with, and it must be a small hole indeed which will not allow the passage of an atom of oxygen. The oxide formed rises up, as it seeks more room than the iron. It is also porous, and is then, in fact, an inlet of oxygen to the metal which is beneath it. As more comes out, the hole becomes larger, the oxide rises up and breaks up the tin in various places, completely enveloping it in rust.

Zinc acts to some extent in a similar way; the comparative value of the processes I do not know. There is less necessity, I believe, to bring in the use of galvanism, in order to explain the mode in which iron throws off other coverings. In the case of earthenware glaze it would be difficult to bring it in at all. In any case, however, *oxygen* must be brought in, and the mode of acting with ware will probably be the same as with the tin. In this case, however, we cannot suppose holes in the surface, but rather at the sides or points of junction, where the oxygen may enter; showing the difficulty of making a *complete contact* between the metal and earthenware.

The first part is a copy of what I intended to say on tin, &c., this last part I have written hastily, as I find I am late. I think it is the true explanation; that, namely, which is given to explain the tin will apply to the earthenware. I was not aware, however, that earthenware came off. I have some on a pan which has lasted a long time the joinings are good.

Professor Way examined.

1. You are professor of chemistry, I believe, to the Royal Agricultural Society?—I am. Professor Way.

2. In the course of your investigations, has your attention been directed to the quality of water from different natural sources, and to the effect of soils upon water percolating them?—For many months I have been engaged on a series of experiments, intended to elucidate the action of soils upon the constituents of manure. The results I have obtained, however, equally apply to the composition of natural waters, and I have more lately directed my attention specially to the latter branch of inquiry.

3. What is the nature of the experiments you have made?—My first experiments were made with tubes, of from 12 to 18 inches in length. These tubes having been partially filled with the soil under examination, I poured upon the surface strong solutions of different alkalies, and alkaline and earthy salts. I found that the first portion of the liquid which came through was absolutely deprived of them. Thus, for instance, if a solution of caustic potash, or of ammonia, containing 1 per cent. of either alkali was made to filter through 9 inches of a soil contained in one of the tubes just mentioned, from one to two ounces of liquid passed through quite pure and free from the substances in question.

4. What was the diameter of the tubes you employed?—They were, as I before said, from 12 to 18 inches in length, and from $\frac{3}{4}$ of an inch to $1\frac{1}{2}$ inch in diameter, and would contain, perhaps, when partially filled, from 1500 to 2500 grains of soil. I have since used much larger filtering jars without, of course, any difference in the character of the result.

5. What were the times occupied in percolation?—When a light soil was employed, and the depth of the filtering bed was 9 inches, the liquid would begin to drop through in 8 or 10 minutes; if a stiff clay were the subject of experiment, it would take much longer to filter, perhaps an hour or an hour and a-half. In these cases, the abstraction of the alkaline substances was complete. In order, however, to ascertain whether a sensible time was necessary for the effect, I forced the liquid in one experiment through the soil, by means of a syringe, with precisely similar results, although the soil and the solution were in contact less than a minute.

6. It does not, therefore, require a lengthened time for the exhibition of the power of which we are speaking?—No; such is the conclusion to which my experiments lead me.

7. Your experiments were made, as we understand, with substances *dissolved*, not merely mechanically suspended in water; the action you are describing is, therefore, different from ordinary filtration?—Totally different.

8. If, for instance, you were to filter a solution of caustic potash through pure sand, you would not expect the alkali to be arrested?—Certainly not; sand would merely stop any solid substance suspended in the water, in the same way that the paper filter of the chemist does. Although, even in the case of a sand filter, very minutely divided solid matter would be liable to escape.

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9. Do you consider the effect to be due to surface attraction, or is it a chemical action?—I believe it to be purely a chemical action, and that the different alkalies are absorbed in the relation of their chemical equivalents or combining proportions.

10. You state that ordinary soils possess this power, whilst pure sand does not; to what ingredient of soils do you attribute it?—I have good reason to believe that the action is due to the clay contained in most soils. I have already stated that sand does not possess the power, whereas a clay, with which I have made many experiments, exhibits the property in a high degree.

11. What kind of clay was that?—The specimen particularly alluded to was a white clay, of the "plastic clay" formation used for pottery. I selected this for my experiments, because it contained no perceptible quantity of organic matters, and well represented the class of pure natural clays.

12. With what other descriptions of soils have your experiments been made?—With three or four loams of different qualities and agricultural value; one of these being the thin soil on the chalk hills of Dorsetshire (Mr. Huxtable's farm), another from Mr. Pusey's estate in Berkshire; also with one or two *agricultural* clays, contradistinguished from the pottery clay before mentioned.

13. In all these cases have the experiments been made with soil free from vegetation?—Yes; there was of course *vegetable matter* in many of them, but no living vegetation.

14. In point of fact, you believe that the effect observed is due to the mineral matter of the soil, and not to plants of any description growing in it, or to vegetable matter in any form?—Most decidedly; that such is the case, is put beyond a doubt by the experiments I have made with potters' clay dug from a depth of 20 feet, and containing no appreciable quantity of vegetable matter.

15. You mentioned that the alkalies and alkaline salts were arrested by filtration through soils; will you state to what salts you have extended your observation?—I have found that the alkalies potash, soda, and ammonia in their caustic state, or in the state of carbonates, are absorbed by soils; in the case of all other salts of these alkalies, such as their sulphates, muriates, or nitrates, the *base only* is arrested, the acid of the salt passing through in combination with lime derived from the soil. Thus, if a solution of sulphate of ammonia is made to filter through a soil which itself yields no soluble salt of lime to water, the ammonia is left in the soil, whilst abundance of sulphate of lime is found in the filtered liquid. The presence of lime in a soil enables it not only to arrest the alkaline carbonates, but the alkaline base of all such other combinations.[1]

16. That is to say, if a solution of any of the ordinary salts of potash, soda, or ammonia is filtered through a soil, the filtered liquid no longer contains such salt, but has taken up in its place a corresponding salt of lime?—Precisely so. If I filter muriate of soda (common salt) through a soil, and analyze the resulting solution, I shall find in it exactly as much muriatic acid (chlorine) as in the original solution; and in the place of soda, I shall obtain a corresponding quantity of lime; in other words, for muriate of soda I obtain an equivalent quantity of muriate of lime.

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17. What would be the effect of passing this filtered solution through a second bed of the same soil? would the muriate of lime be removed by such a process?—Certainly not; the soil has no further power. Indeed, in any filtration of a limited quantity of liquid through a bed of soil of considerable thickness, this double filtration does in reality occur. The change takes place in the first instance in the upper portions of the soil, and the altered liquid has subsequently to pass through a stratum of fresh soil, and yet we find that the *very first portions that pass through*, contain a salt of lime corresponding to the alkaline salt that has been used in the experiment. This is the practical result, and it is easy to see that it should be so. The arresting power of the soil is for the *alkaline base*, not for the whole salt; but it is out of the question that such an action should take place, unless there were something present to combine with and saturate the *acid* of the compound. Lime performs this office for the salts of all the other alkalies and alkaline earths; but its own salts must be an exception to the general rule.

18. Then you are quite unable, by filtration through a soil, to remove from water any of the salts of lime it may contain?—Not exactly so. I before stated, that, besides the caustic or free alkalies, the soil had the power of removing from solution the carbonates of these bases, and that without introducing into the liquid any corresponding salt of lime. In the same way lime, when dissolved in water, as it exists in *lime-water*, which is a solution of caustic or free lime, is entirely separated by filtration through a soil. Carbonate of lime also, when dissolved in water by means of carbonic acid, is entirely removed by passing the water through an ordinary soil or through a pure clay.

19. Then, if I understand you aright, in operating upon a solution of lime, part of which is in the state of carbonate, and part in the state of sulphate and muriate, you can, by filtration, entirely remove the carbonate of lime; but your filter bed will not arrest any portion of the other salts I have named?—Just so. I may further observe, that all the ordinary salts of lime being soluble, are washed from the soil by the water of rain passing through it, which would not be the case, were they compounds, which the soil possessed the power of combining with and arresting.

20. Have you made any experiments to ascertain the extent of this power of soils, and can you state to what amount the abstraction of salts by such filtrations would occur?—I have made a great number of accurate experiments on this point with different soils, and with solutions of salts of ammonia, potash, soda, lime, and magnesia, &c., of various strengths. The method of filtration was not in all these cases adopted, although convenient; it is, indeed, unnecessary to the success of the process; for the power of soils to unite with the alkaline bases is so marked, that you have only to stir up with the solution a quantity of the soil, allowing it afterwards to subside, and the clear liquid will be found either entirely free from the alkali employed, or sensibly diminished in strength. I find that an ordinary loam will absorb about $\frac{3}{10}$ths per cent. of its weight of ammonia, and about one per cent. of potash, and so on for the other compounds of which we have been speaking. This quantity appears small, but it is in reality enormous, when the weight of a given area of soil is considered. Thus, for instance, the soil of an

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acre of land one inch deep will weigh about 100 tons, or 10 inches in depth 1,000 tons. This quantity of soil would therefore arrest, and combine with three tons of ammonia, or 10 tons of potash. To furnish three tons of ammonia, 15 tons of sulphate of ammonia, or nearly 20 tons of Peruvian guano must be employed; so that I am justified in saying that this property of soils is, practically, enormous.

21. To what extent does the separation of carbonate of lime by filtration go?—Under the most favourable circumstances, that is to say, by stirring up the materials, so that every portion of them should come in contact, I find that 100 parts of a soil will absorb about 1½ parts of carbonate of lime; or, comparing this with the previous illustration, you will perceive that an acre of soil 10 inches in depth would arrest 15 tons of carbonate of lime. And we may form a further idea of this power in altering the chemical composition of water, by calculating the effect which the filtration through a soil would have upon Thames water. Supposing this water to contain 14 grains of carbonate of lime in the gallon, it would be found, from the above data, that an acre of soil 10 inches deep would remove the carbonate of lime of about 17,000,000 gallons; or, if the water have to pass through five feet of soil before reaching the drains, 100,000,000 gallons would be purified by the filtration.

22. Your results appear to have a close and practical bearing upon many of the operations of agriculture. But, confining our attention now to the composition of water, will you state what general conclusions as to the quality of water from different natural sources you would be inclined to draw from a knowledge of this property of soils?—Bearing in mind that I attribute the power in question to clay, I should expect that rain-water, falling on a sand, would wash out from it any soluble salts it happened to contain, until, in the lapse of years or ages, nothing soluble remained to be washed out. Falling on a loam or open friable soil, containing a certain portion of clay, it would wash out from it only the soluble salts of lime, such as the muriate and sulphate, if these happened to exist in it. Supposing this soil to be in cultivation, I conceive that none of the salts of the manure would be washed out by rain, except, as I before stated, the soluble salts of lime; but the proportion of such salts washed out by rain would exceed that supplied in the manure, inasmuch as the salts of the other alkalies would be transformed into salts of lime, and be equally liable to be carried away by drainage water. The more perfect the drainage, the more regularly would the water percolate the soil, and every portion becoming active, the more certainly would the valuable salts of manure be arrested to the fertilization of the soil and the purification of the water. Lastly, rain-water passing through a stiff clay soil, providing that it had been well drained, and time had been allowed for the drainage to take effect, would, I conceive, be still less likely to bring away with it any other salts than those of lime before mentioned. If such a clay happened to be free from gypsum, the most common soluble salt of lime, the drainage water would be contaminated only with those compounds of lime derived directly or indirectly from manure, and it would be easy to demonstrate, that the quantity of such salts would, in reference to the rain-fall, be very inconsiderable.

23. Then in good cultivation you include good drainage?—Certainly;

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efficient drainage of soils, not by surface-drains, but by drains at a proper depth, amongst other advantages, seems to offer the additional one of distributing the manuring substances artificially applied, or derived from the atmosphere by rain, through every part of the soil; by this equable distribution of the salts of manure, a perfect immunity from loss is secured.

24. Have you analyzed any drainage-waters?—As yet, I have not completed any analyses of drainage water of a sufficiently pertinent character to be described here. I have, however, arranged with Mr. Parkes the plan of an extensive inquiry into the actual quality of the water of drainage from different descriptions of soils.

25. Without asking you the particular composition of the waters of land drainage, could you state any facts relative to the general characters of such waters?—I am not personally possessed of sufficient information to give an opinion on this subject; but I have been told by Mr. Parkes, to whose experience on such questions I should attach great weight, that the water of deep drainage, especially on clays, was found to be beautifully clear and sparkling, and in many cases of a softness closely approaching to rain water. This statement has been confirmed by all those experienced in drainage of whom I have made the inquiry. One gentleman living in Essex (Mr. Majendie) has told me that having drained some time since some clay lands on his estate, a number of cottagers living near the outfall asked his permission to use the drainage-water for domestic purposes in preference to their usual supplies.

26. You have described the circumstances which would influence the water of drainage; would the same observations apply to land-springs and shallow wells generally?—Yes, the composition of such water would probably be regulated by the character of the superficial strata in the immediate neighbourhood.

27. You are no doubt aware that the water of the artesian wells in the chalk contains a considerable quantity of alkaline salts. How do you account for this circumstance?—The water derived from any stratum will always take the character of that stratum provided there is anything in it that water is capable of dissolving out. In both the upper and lower chalk, many specimens of which have been analyzed in my laboratory, potash and soda have been found in very considerable quantity. These I believe exist partly in the form of silicates, and partly, perhaps, in the form of a double carbonate of lime and potash, or soda, which is of very slight solubility. It is easy to see how water containing an excess of carbonic acid, as the water of the chalk does, would gradually liberate and dissolve out the alkalies from it.

28. Supposing you were to apply the results of your experience to the practice of collecting and storing water, and supposing it were desired to obtain water which had fallen on the surface in the greatest purity, would your experience enable you to express a confident presumption in favour of filtration by percolation through the soil as a means of obtaining pure water rather than collecting it off the surface?—Certainly. My experiments would lead me to believe that water which had percolated the surface-soil to any depth, from 2 to 6 or 8 feet, would, as a general rule, be purer than water either flowing over the surface or taken from greater depths. I have found that different soils possess the power of removing salts from water to a different extent. Water

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which has passed through surface-soil is deprived of its salts to a greater extent than water passing through a soil which has never been cultivated; and there are some kinds of soil (those least fitted for cultivation) which would give up to water any salts they might contain rather than serve to purify it. It is for this reason that I believe that water percolating cultivated soils would, on the whole, be freer from salts than that collected on the surface or taken from great depths.

29. Would not water, after having passed through one description of soil and lost its salts be likely to obtain more mineral matter in percolating other varieties of soil?—Yes; I have before observed that water will possess the character of the rock through which it last flows and from which it issues, unless in the case of sandstone districts, which probably neither give to or take anything from water. I think, however, that from what we now know of the action of clay upon water, we may safely conclude that many other strata of the earth besides the deposits of clay will possess the power of greatly modifying the character of any particular water.

30. Does your experience enable you to prefer any kind of earth, looking to the agricultural objects, namely, the retention of a certain quantity of the salts required, and to the sanitary object of having the water free from such salts as would be injurious or useless? Can you, in fact, point to any one description of soil that, for domestic purposes, would form a better filter than others, supposing the filtration to be by shallow drains near the surface?—I attribute the property in question solely to the clay; and I believe that the circumstance of surface-soils (such as those mentioned before as containing only 30 or 40 per cent. of clay) possessing this power in greater intensity—weight for weight—than pure natural clay, is due to the production of a greater amount of the active substance in those clays which, by cultivation, are exposed to atmospheric and other agencies; but there is plainly a distinction to be drawn between the circumstances most favourable for the mere *collection* of water comparatively pure, like rain-water, and those which would conduce to the purification of a water impregnated with salts, such as the water of all rivers.

31. For the collection of the rain-fall of a given district, what soil would you prefer?—I should say decidedly a sand. Rain-water, when collected at a distance from towns, is fit for every purpose, and contains, I imagine, little which in a sanitary or domestic point of view it would be important to separate. All that is required from the collecting surface in this case is, that it shall perform its office without imparting to the water anything to render it impure. Sands which have been washed by rain for ages are most likely to fulfil this condition, and would possess the further advantage of allowing the ready escape and collection of the water.

32. Have you analyzed the specimens of water given to you by Mr. Paine, of Farnham?—I have examined them to a certain extent.

33. Will you state the result of that examination?—The specimen which I operated upon was obtained by Mr. Paine and myself from the commons near Farnham, being collected from a small well near its source through which the water flows in its way to the town. I found it bright and sparkling, and quite different to what we are in the habit of recognizing in rain-water, which is usually collected in a manner very

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unfavourable to its qualities for domestic or other purposes. The total quantity of salts of any kind in a gallon of this water proved to be 1·5 grains, which so far as I am aware is as small a proportion as is found in any considerable body of natural water from any source. The proportion of lime I found to be ·168 grains in a gallon, which is equivalent to exactly $\frac{3}{10}$ths of a grain of carbonate of lime in the gallon, or $\frac{3}{10}$ths of a degree of hardness of Dr. Clark's test.

34. Was the whole of this lime in the state of carbonate?—I am inclined to think not, since a considerable quantity of chlorine was found in the water, most probably existing as muriate of lime. My analysis of the water has not, however, been complete, for one reason amongst others, which a chemist would readily understand, that is to say, that the water contains so little salt of any kind that it is difficult to evaporate enough of it for analysis without running the risk of introducing as much impurity from the vessels, &c., used in the process as the water itself contains.

35. How would you account for the presence of muriate of lime, or in fact of any salt at all in the water, seeing that it falls on a sand through which millions of gallons of rain-water must have passed in the same way?—It is difficult to answer that inquiry. The sand in question is not a chemically pure sand; but besides the vegetable mould at its surface bearing ferns and heath, veins of clay, intermixed with sand, run through it. It seems to me that the muriate of lime is derived from common salt, brought down by rain and changed by its passage through the little clay in the soil into a corresponding salt of lime. Sea breezes are known to carry common salt many miles into the interior of the country, and the Farnham commons would readily be reached in this way from the south and south-west.

36. Would the muriate of lime be objectionable as an ingredient of water to be employed for drinking and general domestic purposes?—We know little or nothing of the effects upon health of infinitesimal doses of different salts when taken constantly in water; but assuredly if so small a quantity of a salt of lime be objectionable, no natural water on the face of the earth is fit for drinking. As for the hardness of the Farnham water, I have already stated that it only reaches $\frac{3}{10}$ths of a degree of hardness, that is to say, $\frac{1}{50}$th of the average hardness of the Thames at Hammersmith.

37. In both a sanitary and an economical point of view you would, then, consider such water of proper quality for the supply of the metropolis or of any large town?—Undeniably; I have before stated my belief that rain-water collected in a pure atmosphere, and on surfaces uncontaminated with decaying animal or vegetable matter, or with soot, &c., is the most perfect form of water. It is, in fact, the nearest approach to *distilled* water; but having the advantage over artificially distilled water of being well aërated, and therefore agreeable to drink. I consider the water of Farnham, of which we are speaking, to be *rain-water*, collected in the most unexceptionable manner that is practicable on the large scale.

38. What would you recommend as to the treatment of such collecting surfaces for improving or preserving the quality of water so derived? what sort of vegetation would you encourage? or would you take measures to destroy, as far as possible, all kinds of vegetation?—I would

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certainly encourage some sort of vegetation, in order that the ammonia and other matters, mineral and organic, brought down from the atmosphere might be used up, and prevented from contaminating the water. I do not feel competent to give an opinion as to the kind of plants which it would be best to have on these collecting grounds, but they should be such as would not need the application of manure of any kind; an application which, on such a soil, would directly or indirectly be productive of injury to the quality of the water. It would of course be desirable that if any kind of produce could be made to grow on such soils without manure, it should be such as to repay the cost of collection; and for the same reason that I should object to direct manuring, I should object also to the extensive feeding of cattle or stock of any kind on that produce as it grows.

39. You mean that the produce, if any, should be carted off the land?—Decidedly; and I mean, further, that in order to keep up the balance in the composition of the soil, and to prevent the accumulation of matters derived remotely from the atmosphere, a certain quantity of produce should, in a given time, always be removed.

40. Has no kind of plants occurred to you as likely to meet these requirements?—Perhaps *gorse*, if it could be made to grow in such soils would be the very best produce to encourage; a canal or canals running into the Thames pass through the very centre of the district. Gorse, when properly prepared, has been found an excellent food for stock; and I have heard that its good effect upon horses, racing and pleasure-horses especially, is remarkable. It has been used, I believe, in the stables at Ascot, and gives a singularly smooth coat and other healthy character to horses fed upon it. I can conceive that being properly packed, it would economically be brought by barges to London for the use of stable and cow-keepers, and afford a profit upon its cultivation.

41. Does your observation enable you to say whether gorse or furze would grow on such commons?—I cannot say. I have seen it on the same kind of soil in many parts of Surrey and in parts of Kent, as at Tunbridge Wells (where the soil is a gravelly sand), on what is called by geologists the "Hastings sands," gorse flourishes in great luxuriance. It is said, however, to delight in a heavy clay subsoil; and it may be doubted whether the sandy commons would be suitable to it, except where the clay below comes tolerably near to the surface.

42. You are then clearly of opinion that, for the preservation of the water in its integrity, the collecting grounds should not even, if otherwise practicable, be brought into general cultivation?—Yes, unless by the admixture of clay the manure-retaining properties of the soil could be increased.

43. We have hitherto spoken of the circumstances affecting the quality of water as regards salts and other mineral impregnations. Do you possess any information bearing upon the vegetable or animal substances occurring in water, and the possibility of purifying water so contaminated?—My experiments on soils have been extended with considerable success to this branch of the question. I have passed various animal and vegetable solutions, such as stinking cow's urine, sewer-water, putrid human urine, the water produced by the steeping of flax, &c., through filter-beds of soil; and when passed through they have

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been entirely deprived of smell and taste, except an earthy smell derived from the soil.

44. Were these solutions offensive to the smell?—Yes; they were highly offensive and coloured; and the liquid dropped from the filtering-soil so colourless and inoffensive, that it might be even tasted without disgust. It was, in fact, a mere solution of various salts of lime.

45. You think that mechanical separation of suspended animal and vegetable matter would not have produced the same result?—Certainly not. I have over and over again filtered these same liquids through beds of fine sand, without in any degree removing these offensive properties. And as in the case of the absorption of potash, ammonia, &c., by soils, this deodorizing process can be effected without filtration by simply stirring up the liquid and the soil together; when this latter subsides, the solution will be found colourless and devoid of smell and taste.

46. Are you aware that it has been stated that in the surface distribution of sewer-water by jet or hose, all trace of smell disappears in half an hour after the manure has been applied to pasture-land?—Yes; and although no doubt plants begin the absorption of manure in solution immediately it is presented to them, there is no doubt that the observed effect is due to the soil and not to the plant, and that the result would be the same if the sewer-water were applied to arable land not at the time bearing a crop.

47. Do you attribute the effect of soils upon organic matters also to the clay contained in the soils?—Yes.

48. By filtration of the water of rivers containing salts, giving hardness and different animal and vegetable matters in solution through a bed of soil, you can remove all these and produce comparatively pure water?—I can, with the exception of those salts of lime before enumerated, and such other salts of lime as will be formed from alkaline sulphates, muriates, and nitrates. I have in this way reduced Thames water of 15 degrees of hardness (15 grains of carbonate of lime in the gallon) to less than 2 degrees of hardness, and rendered it soft and pure.

49. Do you imagine that any such filtering process is applicable to the preparation of water for towns like London?—It would require great and careful consideration to give a satisfactory answer to that question, the quantity of water required for London being so enormous; but I should by no means despair of its applicability to other towns where the necessary supply is more limited.

Second Examination.

1. What do you conceive will be the effect of soft as compared with the common hard water for the reception and removal of human fæces and urine, and its application as manure?—I am not aware that in this point of view soft water would possess any notable advantage over ordinary hard water.

2. What will be the effect of the immediate reception of such matter

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in cold water, and its immediate removal in cold water, as compared with the effect of its removal after exposure to the atmosphere during one or several days, the effect upon the productive value and quality of the matter as manure?—As a question of the agricultural application of sewage manure, there is an easy answer to this on general principles. The offensive smells and noxious gases that are given off in defective sewerage are for the most part caused by those substances which are the most valuable ingredients of manure, that is to say, by the compounds of nitrogen, sulphur, and perhaps of phosphorus; just in proportion, then, as our noses are offended and our health undermined by these exhalations will be the loss suffered in the manuring power of the matter which gives rise to them.

3. What do you expect will be the nature of the emanations from fæces immediately received and removed in the proportion of half-a-gallon to one gallon of cold water each time of discharge?—The fæces and urine when first voided have but little smell, and that little in the case of the former is, I imagine, due to the biliary and other secretions, and in no way connected with the escape of any notable quantity of gaseous matter. It is not until after these have been exposed for some time to the combined action of air and water that decomposition can commence, and noxious gases be given off. If, therefore, the fæces and urine could be received in the quantity of water you mention, and at once removed by it, the cause of offence to the senses and the health would, it should appear, be reduced to a minimum.

4. Since your last examination you have, I believe, received another quantity of water from Farnham?—I have.

5. Have you made any analysis of it, and if so, describe the results you have obtained?—I have made a tolerably complete analysis of this second specimen, and find it to differ considerably from the one before sent to me. It is right that I should mention that, in forwarding the jars of water at my request at the early part of last month, Mr. Paine informed me that, owing to the unusually heavy rains, and to the very recent cleaning out of the wells through which it has to pass in its progress to the town, the water was by no means in its ordinary condition; circumstances, however, would not allow of my delaying the analysis till another sample could be procured. I found this water to contain 5·191 grains of solid matter in the gallon, or more than three times as much as the previous specimen. The following analysis exhibits the composition of this solid residue:—

	Grains.
Organic matter and combined water	1·245
Silica	·550
Lime (as silicate?)	·375
Sulphate of lime	·280
Sulphate of magnesia	·557
Chloride of magnesium	·522
Chloride of sodium	1·440
Chloride of potassium	·354
	5·323

This water is very peculiar in one respect; it contains, so far as I

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have been able to observe, no trace of carbonate of lime, or of any other earthy or alkaline carbonate. The product of the evaporation of upwards of two gallons of the water (the final evaporation being effected by a heat short of 300° Fahrenheit) did not give a perceptible efferves- cence with hydrocloric acid. The presence of organic matter which, in the former instance, was barely recognizable, together with the com- paratively large proportion of common salt, and of other chlorides, suf- ficiently convinces me that the water had been affected by disturbing causes of an unusual character.

6. You think, then, that the sample of which you have given the analysis would exhibit, in all probability, the latitude of impurity to which the water of the Farnham commons is liable?—Taking all the circumstances into consideration, and comparing the results with the partial examination which I made of the former specimen, I should say —yes.

7. In this its worst condition, would the water, in relation to its application to domestic and other purposes, be preferable to that now generally supplied to the metropolis?—I have no doubt that it would; the degree of hardness was, 2° and although less bright than at other times, it was still wholesome and agreeable to drink.

8. Does it occur to you that, in addition to the general causes of disturbance to which you have alluded, any other local cause may have contributed to render this particular specimen of water less pure than usual?—I have not made inquiries upon this point, but I can quite conceive that if the soil of the garden or gardens beneath which the pipes are carried, and in which there is access to it by small bricked wells as I before described, had been lately manured, some portion of the manure might have found its way into these wells, and thus contaminated the water. The soil of the gardens must in most respects closely resemble that of the commons, which is, by its sandy nature, and the comparative absence of clay, very little adapted to retain manure; and although I am not prepared to say that such has been the case, it is not impossible. The water was examined for nitric acid, which (from Dr. Smith's experiments) should be one of the products under such circumstances, but it could not be detected. I may be allowed to remark, in this place, that the bare possibility of such a contamination having taken place shows the necessity for the precautions (with regard to manure, &c.) which I have before urged, in case these sandy commons should be used as gathering grounds for the supply of the metropolis with water.

9. Have you in the course of your agricultural inquiries turned your attention to the employment of sewage as manure, and to the mode by which it might be made most generally available?—This subject has, as might be expected, appeared to me, as to most persons engaged in the same pursuits, of the very last interest and importance, and especially in relation to the experiments on the absorptive powers of soils I have before described.

10. Have you analysed the contents of any London sewer?—I have.

11. Would you describe to the Board the nature of your examination of sewer water?—Two specimens of sewer water were sent to me by direction of the Board from the office of the Commission of Sewers.

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The one of these was taken from a sewer in Dorset-square, the other from a place called Barratt's-court. The analyses were made for me by Mr. Ogston. In analyzing them measures were taken to separate the solid suspended matter from that actually in solution, so that the manuring nature of each might be clearly ascertained. The solutions were strained through a fine cloth; the solid substances were dried, and the quantity of salts in solution ascertained by evaporating the liquid with proper precautions to avoid loss of ammoniacal salts. The following table shows the relation between the soluble and suspended matter:—

No. 1, from Barrett's-court.

The imperial gallon contained—
Of substances in solution . . . 243·30 grains.
Of insoluble substances . . . 248·96 „

No. 2, from Dorset-square.

In the imperial gallon—
Of substances in solution . . . 109·00 grains.
Of moveable substances . . . 100·70 „

The quantity of substances at any time present in a given quantity of sewer water will be dependant on many circumstances, particularly on the time of collection and the nature of the water supply. This circumstance accounts for the first specimen containing twice as much matter dissolved in the solid state as No. 2. The relation between these is, however, of equal importance, as their total quantity in reference to the water and in the two cases a certain proportion between soluble and insoluble is retained. But I am not prepared to say that such an uniformity would be found to obtain in other specimens. The following tables exhibit the composition of the soluble and insoluble substances in these specimens of sewer water.

Analysis of Sewer Water.—No. 1. From Barrett's Court.

	An Imperial Gallon contains (in grains and tenths)—		
	Soluble.	Insoluble.	Both.
Organic Matter and Salts of Ammonia	121·50	180·32	301·82
Sand and detritus of the Granite from the Streets	*1·39	19·30	20·69
Soluble Silica	1·57	10·94	12·51
Phosphoric Acid	7·71	2·73	10·44
Sulphuric Acid	10·71	4·02	14·73
Carbonic Acid	11·62	3·97	15·59
Lime	7·50	17·03	24·53
Magnesia	2·87	Traces.	2·87
Peroxide of Iron and Alumina	Traces.	6·20	6·20
Potash	46·91	1·22	48·13
Soda	None.	1·51	1·51
Chloride of Potassium	None.	None.	None.
Chloride of Sodium	31·52	1·72	33·24
	243·30	248·96	492·26

* This is some small proportion of insoluble matter escaping the linen filter, and properly belonging to the other column.

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The insoluble and soluble matters are both capable of supplying nitrogen or ammonia to vegetation. The solution contains the nitrogen in the form of ammoniacal salts, and it is a circumstance of great interest and practical importance that *all the nitrogen* in the liquid state seems to be in the form of ammoniacal salts—the urea and other animal products having rapidly passed into this condition. The insoluble matter contains, of course, no ammoniacal salts, its nitrogen being referrable to unchanged animal matters. The quantity of ammonia in the soluble and insoluble state in a gallon of sewer water, calculating the nitrogen of the solid matter as if it had passed into ammonia, is as follows:—

Ammonia in a gallon—

In the soluble state . . . 36·72 grains.
In the insoluble state . . . 4·56 „

Analysis of Sewer Water. No. 2.—From Dorset Square.

	An Imperial Gallon contains (in grains and tenths.)—		
	Soluble.	Insoluble.	Both.
Organic Matter and Salts of Ammonia	57·32	23·00	80·32
Sand and detritus of the Granite from the Streets	0·78	44·50	45·28
Soluble Silica	1·16	12·09	13·25
Phosphoric Acid	2·53	1·64	4·17
Sulphuric Acid	0·28	3·63	3·91
Carbonic Acid	10·58	1·99	12·57
Lime	7·40	8·37	15·77
Magnesia	·07	Trace.	·07
Peroxide of Iron and Alumina	Trace.	2·66	2·66
Potash	2·60	0·72	3·32
Soda	None.	None.	None.
Chloride of Potassium	None.	None.	None.
Chloride of Sodium	27·27	2·10	9·37
	109·00	100·70	209·70

Ammonia:—

In the soluble state . . . . 15·16
To be formed from the soluble matter . 2·80

It will be observed that the most valuable elements of the nutrition of vegetables reside chiefly in the soluble portion of the sewage water. The greater part of the nitrogen (ammonia) of phosphoric acid, sulphuric acid, and potash, being found in solution. Any process, therefore, of ordinary filtration or deposition, by which the solid portion only could be rescued, would be very imperfect.

Supposing the sewer water you have analyzed to be thrown upon a soil, would these valuable matters you have mentioned be arrested by the manure-retaining properties of the soil, or would they in any degree be lost?—I have made an experiment upon this point, and with the permission of the Board I will describe it. A quantity of a loamy soil was placed in a glass cylinder to the depth of 6 inches, upon this a quantity of the sewer water, No. 1, was thrown; it began to pass through in about 10 minutes, and in two hours afterwards a quantity

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rather more than equal in weight to the quantity of soil employed has passed through. The solid matter of the sewer water was, of course, arrested mechanically. The clear liquid being analyzed furnished the following results:—

The quantity of solid matter in a gallon being 248·50 grains.

Organic matter *containing no nitrogen* .	60·58
Chloride of sodium	52·73
Chloride of magnesium	·67
Chloride of calcium	8·89
Carbonate of lime	104·98
Sulphate of lime	17·49
Loss on the analysis	3·16
	248·50

The liquid contained no potash, no ammonia or nitrogen in any form, and no phosphoric acid. The soil had, therefore, deprived it of its most valuable ingredients.

Then in the application of sewer water to a good well-drained permeable soil you would not fear loss of the manuring substances by the escape of the water in the drains?—Certainly not. The experiment I have just mentioned would be an absurdly exaggerated manuring by sewer water. In filtering its own weight of water through the soil I am employing a dose of manure that would never be given in practice. Thus supposing the active surface to be 10 inches deep, it would, as before stated, be 1,000 tons in weight on an acre. Now 1,000 tons of sewer water would be 224,000 gallons, which, according to the analysis, would furnish about half a ton of real ammonia, and other things in proportion. In other words, to put on a quantity of sewage of this strength, equal to the weight of the soil to 10 inches deep, would be to manure an acre of land with three tons of Peruvian guano, which is fully 20 times the quantity that would actually be used. Therefore, I say that in practice this power of the soil would, doubtless, give much more favourable results than were obtained in my small experiments.

Have you formed any calculation of the money value, in an agricultural sense, of the water of sewage, supposing means existed for its ready distribution?—It would not be difficult to obtain an approximation to this result if our calculations were based upon the composition of any particular specimen. Thus the Barratt's-court sewer gave about 37 grains of ammonia in a gallon in the liquid state, and about 4½ grains more that would be formed from the animal matter not dissolved. Calling this 40 grains altogether, we should have in 100,000 gallons about 570 lbs. of real ammonia. The recognised value of ammonia, as shown by the price given for Peruvian guano, is about 6*d*. a pound, so that the ammonia alone of this 100,000 gallons of sewer water is worth more than 14*l*.

And the potash, phosphoric acid, and other substances, would make a material addition to this value?—Yes.

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Third Examination.

1. At the request of the Board, you lately visited, in company with Dr. Smith, a portion of the Surrey commons, with the view of examining the water on the spot: be good enough to describe the result of your examination?—I have twice within the last fortnight accompanied Dr. Smith into Surrey. On the first occasion (the 11th of May) we visited the Bagshot district; examining all the streams and collections of water near Farnborough, Bagshot, Chobham, Pirbright, &c., including an area of perhaps more than 50 square miles. On the second occasion our attention was directed to a district to the south of the above, comprising the country between Guildford, Dorking, and Godalming, and their respective neighbourhoods.

2. What was the general character of the water of the Bagshot district?—The water running from the sandy commons was in general very soft; it was, however, in many cases impregnated with peaty matter, which gave it a brown colour, and in some instances it had a perceptible taste of iron; both of which circumstances are of course objectionable.

3. Did you consider that the peaty and irony taste were a *necessary* condition of that water; or would it, do you think, be possible to avoid these characters, so that the water of the districts of which we are speaking might be safely used with that of the other districts where these objectionable characters do not obtain?—From all that I saw, I was led to the conviction that the water, if properly collected, would be free from these impurities; or that, supposing it impossible to *prevent* the contamination, it would be easily and economically removed.

4. Can you state any circumstances seeming to justify this conclusion? first in regard to the water obtaining the peaty matter and iron; where do you think it obtains these?—A large part of this district is covered to a variable, but, I believe, small depth with peat mixed with iron sand, which may be supposed to yield both these substances to water. It does not appear to me, however, that the rain-water in falling and sinking *through* the surface dissolves them, or, if it does, I think that they are removed in the passage of the water through the sand at a greater depth. My reason for thinking as I do is, that small wells to the depth of perhaps two or three feet on these commons furnish water of good quality and quite free from peaty or irony matter; and again the Farnham water which I have before described, and which is obtained from land of a similar quality in most respects, is quite free from such matters; no doubt, because it is obtained *from beneath* the surface. The water appears to dissolve the peat in passing through the natural conduits or small streams on the surface, where it attacks the vegetable matters on the banks assisted by the full action of the air.

5. Drainage by pipes at a short distance from the surface would then seem the remedy for this state of things?—It would appear so, and it is in accordance with the successful experiment in collecting such water at Farnham.

6. You stated that if the water so collected should prove to be peaty, or impregnated with iron, it might readily be purified; how do you imagine this would be done?—Dr. Smith and I observed that the water, in flowing in the shallow streams, deposited large quantities of ochreous matter on the pebbles at the bottom, and just in proportion as this occurred, so the water seemed to get purer. The streams were

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better as they reached the outskirts of the district than they were near the peaty centre, and altogether the water seemed to purify itself in running. One instance of this view, which might indeed in some degree be referred to the purifying power of clay, may be worth mention. A stream at a certain point north of Woking Common was found to be unexceptionable in colour, taste, and softness. Two miles further up, towards its source, it was peaty and bad tasted. The country between these points was of very different character to the general district, being a tolerable soil, and in cultivation. It is possible, therefore, that the effect might in part be due to the action of the clay banks, upon the water running between them. But, whatever the cause, it would appear easy to imitate it, when it is fully understood.

7. You think, then, that the water of the Bagshot district will be eventually obtained in a condition of satisfactory purity?—I believe that, if it should be found impracticable by under-draining, or attention to the natural surface-conduits, to obtain it free from peat and iron, these substances will be readily removed by simple processes in imitation of those which are found naturally to purify it.

8. What opinion did you form of the water in the neighbourhood of Guildford, Dorking, and Godalming?—The stream and pieces of water were for the most part soft, and otherwise good water; in some cases, indeed, remarkably soft. The quantity of water did not, however, appear to be great; but of this I can form no proper opinion. The district is for the most part rich, and consequently cultivated; it would therefore, I presume, not admit of the same means for collection of water as the sandy wastes in other parts of the county.

Examination of Samples of Water from Street Drainage, taken from the Gullies in the Sewers during the rain of 6*th May*, 1850.

The waters were all more or less turbid, and some of them gave off very noxious odours, due principally to the escape of sulphuretted hydrogen gas.

Some of them were alkaline to test-paper, but the majority were neutral.

The following table exhibits the quantity of matter (both in solution and in the solid state) contained in an imperial gallon of each specimen.

Street Waters.

Number of Bottle.	Name of Street.	Quality of Paving.	Quality of Traffic.	Residue in an Imperial Gallon.		
				Soluble.	Insoluble.	Both.
				Grains.	Grains.	Grains.
1	Duke-street, Manchester-square	Macadam	Middling	92·80	105·95	198·75
7	Foley-street (upper part)	,,	Little	95·13	116·30	211·43
5	Gower-street	Granite	Middling	126·0	168·30	294·30
12	Norton-street	,,	Little	123·87	3·00	126·87
3	Hampstead-road (above the canal)	Ballasted	Great	96·00	84·00	180·00
4	Ferdinand-street	,,	Middling	44·00	48·30	92·30
2	Ferdinand-place	,,	Little	50·80	34·30	85·10
10	Oxford-street	Granite	Great	276·23	537·10	813·33
6	,,	Macadam	,,	194·62	390·30	584·92
11	,,	Wood	,,	34·00	5·00	39·00

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The influence of the quality of the paving on the composition of the drainage water is well seen in the specimens Nos. 10, 6, and 11, all of them from Oxford-street, the traffic being described as "Great."

The quantity of soluble salts is here found to be greatest from the granite matter from the macadamized road, and very inconsiderable from the wood pavement.

The same relation between the granite and macadam pavement, seems to hold good in the other instances; the granite for any quality of traffic affording more soluble salts to the water than the macadam.

The ballasted pavement holds a position intermediate between the macadam and the wood, giving more soluble salts than the wood, but less than the macadam.

The quantity of solid (insoluble) matter in the different samples of water, which is a measure of the mechanical waste of the different kinds of pavement, appears also to follow the same relation as that of the soluble salts; that is to say, granite greatest, next macadam, then ballasted, and lastly wood pavement, which affords a quantity of solid deposit almost too small to deserve notice.

The influence of the quality of traffic on the composition of the different specimens of drainage is well-marked in nearly all cases; the greatest amount of matter both insoluble and soluble being found in the water obtained from the streets of great traffic.

It is worthy of notice, however, that the composition of the water is very much the same for similar qualities of pavement in those streets where the traffic is described as "Middling, or Little."

The quantity of water at disposal (one-tenth of a gallon of each specimen) was not sufficient to allow of a complete analysis in each case.

The following table, however, shows the composition of the soluble salts of four specimens, two of them being from the granite, and two from the macadam pavement.

Analysis of the Soluble Matter in different Specimens of Street Drainage Water.

—	Grains in an Imperial Gallon.			
	Great Traffic.		Little Traffic.	
	Granite. No. 10.	Macadam. No. 6.	Granite. No. 12.	Macadam. No. 7.
Water of combination and some soluble organic matter	77·56	29·07	22·72	13·73
Silica	·51	2·81	..	..
Carbonic acid	15·84	12·23	None	None
Sulphuric acid	36·49	38·23	46·48	34·08
Lime	6·65	13·38	25·90	16·10
Magnesia	None	23·51	Trace	3·50
Oxide of iron and alumina, with a little phosphate of lime	2·58	1·25	..	..
Chloride of potassium	None	10·99	None	2·79
,, sodium	53·84	44·88	18·44	19·70
Potash	82·76	18·27	8·75	5·23
Soda	..	..	1·58	..
	276·23	194·62	123·87	95·13

It will be seen that the soluble matters of the different specimens of

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water consist of salts of potash, magnesia, lime, and soda. The quantity of sulphuric acid (in the state of sulphates of lime and potash) seems to be very little influenced either by the quality of the pavement, or the quality of the traffic; and it would seem probable that it owes its origin to the large quantities of sulphur daily thrown into the air from the coal burnt in the metropolis. This sulphur, in whatever form it might originally exist in the air, would rapidly be oxidated and brought down in tolerably equal quantity in the different streets.

It appears from the table, that the granite furnishes little or no magnesia to the water, whilst the quantity from the macadam is considerable.

On the other hand, the quantity of potash is far greatest in the water derived from the granite.

The traffic, as was before seen, has a very great influence on the quantity of the soluble salts. It seems also to influence their composition, for we find no carbonates either in the water from the granite, or that from the macadam where the traffic is little; whereas when it is great, carbonates of lime and potash are found in the water in large quantity, a circumstance which is no doubt attributable to the action of decaying organic matter on the mineral substances of the pavement.

The waters contain small quantities of salts of ammonia in solution, but their proportion was not ascertained.

The insoluble matter in the waters consists of the comminuted material of the road itself, with small fragments of straw and broken dung.

The relation between the mineral and organic portions was ascertained in three samples, and was as follows:—

	Per Cent.	Insoluble organic matter in the Gallon.
Number 5	24·00	40·39
,, 6	14·48	56·51
,, 10	38·39	220·01

The quantity of soluble salts (especially of salts of potash) in many of these samples of water is quite as great, and in some cases greater than that found in the samples of sewer-water that have been examined;* and it is open to question and further inquiry, whether the water obtained from the street-drainage of a crowded city might not often be of nearly equal value as liquid manure with the sewer-water with which it is at present allowed to mix.

Two specimens of water collected from the roofs of houses were examined; they were slightly turbid, with a black matter (soot). The following was found to be their composition:—

	Grains in the Gallon. Insoluble.	Soluble.
No. 8, Albion-street, Caledonian-road, slated roof. .	30	12·0
No. 9, Winchester-street, Pentonville, tiled roof . .	Very small	12·80

The quantity was too small for quantitative analysis, but it was ascertained that the soluble matter in both these waters was principally and almost wholly composed of sulphate of lime, having no doubt a similar origin to that found in the street-drainage water, namely, the sulphur given off in the combustion of coal. It would appear that water thus collected in London is of half the impurity and half the hardness of Thames water.

J. THOMAS WAY.

1st *October*, 1850.

* By Mr. Lovick's inquiries, and two analyses of sewer-water made by myself.

Letter from Thomas Spencer, Esq. (of Liverpool) respecting the Action of Water upon Lead. Mr. Spencer.

Sir, *Liverpool*, 9*th May*, 1850.

Being requested to draw up an abstract of my opinions relative to the chemical action which ensues between different qualities of water and lead, I beg to lay the following brief paper before you.

I may premise that the views I entertain are derived from the results of numerous experiments, some of which have been made and recorded by others, but which have been subsequently repeated and verified by myself.

Another portion, however, is advanced, as far as I am aware, for the first time. I allude to those which show that the oxide of lead is dissolved by most of the salts contained in hard water.

That perfectly pure water wholly deprived of air does not oxidise lead, is admitted by all who have given attention to the subject.

This is, perhaps, better expressed when we say that "lead does not possess the power of decomposing water," and it is also more in accordance with the views of science. Water, however, is never found absolutely pure or free from air. On the contrary, it usually contains mineral, organic, and gaseous matters in solution. Sometimes one class of bodies predominate, sometimes another, but not unfrequently all three are present. Moreover, when in its purest natural state as rain, water is always mingled with the atmosphere through which it falls; hence it not unfrequently contains gaseous matters derived from smoke. For the subject under inquiry, all foreign bodies found in water must strictly speaking, be looked on as impurities, as we know that they influence the chemical action between water, lead, and air. Although air is the prime oxidizing agent, yet it is only in connexion with water that it is so; as the oxygen of perfectly dry air does not combine with lead at common temperatures. But air does not exist naturally in a perfectly dry state, but is always more or less combined with water. On the other hand, water in its natural state is never found without air. Even boiling it does not absolutely deprive it of all the air which it contains.

In pursuing the inquiry we have, therefore, to consider the effect which these bodies have upon lead when they are dissolved in water. Both practice and experiment show that air and moisture, when combined, are alone sufficient to oxidize lead, although they do not possess the power of rendering the resulting oxide soluble; *this second action being altogether due to the mineral or organic substances which the water may happen to contain.*

The first and only chemical change then, which takes place *in pure water* when in connexion with lead, is the formation of a hydrated oxide on the moist surface, say of a cistern. This chemical change is effected by the united action of air and water alone; but should the same take place *in hard water*, which on exposure it is more than equally liable to do, then the oxide will be taken up and held in chemical solution, and thus it becomes diffused throughout the volume of water. If therefore, the salts which give to water its hardness were not present, the oxide could not be held in chemical solution. Indeed, when the oxide forms in soft water, its tendency is to remain on the surface of the lead, either in that state, or, if much exposed to air, as a car-

Mr. Spencer. bonate. Should agitation or any other circumstance cause its removal, it has no power of diffusing itself chemically throughout the water, since we find that it may be separated by filtration, so that the most delicate tests are unable to detect it.

We thus arrive at two conclusions: one, that air and water jointly form an oxide which *is insoluble in soft water;* the other, that hard water and air also form this oxide, but that *in the latter it becomes soluble.* We are therefore fully justified in stating that hard water in connexion with lead is more dangerous than that which is soft.

Having thus far stated the general case, we have now to consider the circumstances which arise in practice. Although the abstract fact is generally admitted, that *perfectly pure* distilled water, totally deprived of air, does not oxidise lead, yet the question has been usually discussed as between rain-water on the one hand, and hard water derived from springs on the other. Those who have reported on the action of water on lead, as far as I can learn, have used rain-water caught within or not far from a town, for their experiments. Now rain-water not only contains a larger proportion of air than water which is taken from a surface-brook, but the rain of a town can never be said to be altogether free from fine particles of soot, as well as gaseous matter derived from the combustion of coal. Even filtration does not altogether remove these matters, as their particular taste is still perceptible.

There is therefore no doubt that, under these circumstances, slips of brightened lead become more rapidly tarnished when immersed in such water, than if in ordinarily hard or spring water. In proof of which I may state, that where experiments have been made with rain-water, caught at a distance from a town, the lead remained comparatively untarnished, as in distilled water. On the other hand, where similar experiments have been made with hard spring-water, it has been inferred, because the lead has sustained little diminution of brightness, that no oxidizing action had taken place, and therefore that hard water is less dangerous in connexion with this metal than soft water.

But the fact has been altogether overlooked, that some of the earthy salts, which give to water its hardness, have the power of dissolving this oxide as soon as formed, and therefore operate to prevent an oxide from depositing itself on the surface of the lead; thus keeping it bright, and at the same time leading to the conclusion, that it has continued unacted upon, even when the water has remained exposed to the atmosphere. Those who have observed the destructive effects of hard water on cisterns, especially in Liverpool, where the water is pre-eminently hard, but who have not studied the matter chemically, have been at a loss to account for some of the scientific opinions so much at variance with their daily observation. In a word, the closet-experimenter has usually come to the conclusion, that *soft water only* acts upon lead, while the practical observer finds that cisterns are more rapidly corroded by hard water: hence has arisen so much conflicting opinion. A little reflection, however, will render it obvious that the effects of practice can scarcely be observed by the mere immersion of slips of brightened lead into glass vessels containing either hard or soft water, and there suffering them to remain for a few weeks, perhaps only so far covered as to prevent evaporation or the accession of dust.

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To have made experiments that would realise the practice, the whole circumstances of an intermittent supply ought to have been taken into account.

It must be recollected also that, as cisterns are constructed, lead is not the only metal which has to be dealt with; there being the solder which is used for the joints. Now this substance, which is an admixture of lead and tin, will, when immersed in water along with lead, act as a distinct metal, and give rise to a voltaic action between the lead, the solder, and the water. This will cause a rapid corrosion at the joints, but it will be more or less active *in proportion to the hardness or chemical impurity of the water.*

Those who have given attention to the principles which govern electro-chemical action, can have no difficulty in understanding this, and that were the water perfectly pure, such an action could not take place.

We have next in the order of practice to take into account that intermittent filling and emptying, which so frequently expose the sides of a leaden cistern to the united action of air and moisture. This also considerably accelerates the formation of the oxide. Indeed, I believe that it tends to its production more than any of the circumstances connected with a cistern. That it is much influenced by evaporation, there can be no reasonable doubt. In proof of which we find, that where the water of a cistern is kept at the same level by constantly adding as much as is taken away, thin lead will soon be cut through *at the water-line*, or, rather, the line of evaporation. Under the same circumstances the effects produced by soft water are comparatively slight. Were lead upon roofs to be as often sprinkled with hard water as it is with rain, and taking into account the rapidity of evaporation, the duration of this metal under such circumstances would be much more limited than we know it to be.

It is the opinion of some that the earthy salts which are contained in hard water operate to prevent this metal from being diffused or oxidized. On any principles of recorded science, it is difficult to understand how a salt in solution can operate to prevent corrosion of a metal, except where it may be said to neutralize an acid. But in this instance there is no acid present; as carbonic acid, as it exists in air, can scarcely be called so, as it does not act upon lead until after the oxide has been formed.

That a neutral salt in solution can afford what, for want of a better term, might be called a catalytic protection to a metal, is so contrary to analogy, that on strictly chemical grounds it is scarcely reconcilable.

But if sulphates and silicates afford the protection they are said to do, it can only be understood on the principle that when water contains a salt in solution it becomes, for lack of room, less capable of containing another body than when purer, and this in the direct ratio of its approach to saturation.

In this sense such protection becomes strictly mechanical, and is better expressed when we say that water which contains another body in solution, necessarily possesses *less* intersticial space than when unoccupied.

On this principle we can also conceive how it is that rain-water contains more air than water which is preoccupied by mineral salts.

Mr. Spencer. Altogether independent of this, however, I find by experiment that neither the sulphates nor the silicates which are found in water have the power of dissolving oxide of lead. We are thus far positive, therefore, that the presence of these bodies, as far as lead is concerned, is much less objectionable than most of the other salts which are found in spring water.

We now arrive at the consideration of these salts of hard water which may be proved to be positively objectionable, in connexion with lead. I had been aware, from observation and experiment, that hard water not only oxidized lead when exposed to air, but that it also dissolved and consequently held such oxide in solution, but which latter property was *not* possessed by soft water. I found likewise that waters taken from different wells, and which indicated the same degree of hardness according to the scale, yet their action upon lead differed very materially; the water of one well, for instance, dissolving more oxide of lead in a given time than that taken from another: the fact being inferred from the variable discoloration of the water by sulphuretted hydrogen, which fairly indicates the quantity of oxide dissolved in a given time. I have also found that the formation of the oxide itself takes place more rapidly in some waters than in others, where the degrees of hardness are alike. It seemed, therefore, tolerably clear that this disparity must arise from the different properties of the salts contained in the waters. Nor was there much difficulty in arriving at this conclusion, as the chemical constitution of our Liverpool waters differ so considerably from each other. For example, we find that water taken from two wells, each of which shall indicate, say 18° of hardness, according to the scale laid down by Clarke, yet one of them shall contain 12 grains of magnesia to the gallon, while the other may contain only 4 or 5; but, on the other hand, the first water may contain only 5 or 6 grains of lime, and the other will then contain 12 or 13 of the same substance. Now, although in the usual acceptation of the term these waters are nearly of equal hardness, yet, it being derived from difference of chemical constitution, the action upon lead will differ materially.

It is perhaps not unworthy of remark, that in sandstone districts the spring water varies considerably in chemical constitution; even where the wells are little apart from each other.

General observations of this nature, led me to examine the salts of hard spring-water separately, to ascertain if possible which of them exerted the most power in dissolving the oxide of lead, seeing that wherever water is exposed in open leaden vessels this substance is always formed.

After making a series of experiments to ascertain this important point with the waters of various wells, the chemical constituents of which I had previously ascertained by analysis, I arrived at the following conclusions:—

First. That, as a rule, most of those salts which give to water its hardness are capable of dissolving the hydrated oxide of lead.

Secondly. That their solvent power is unequal.

It would follow, therefore, that those salts which possess the solvent power in the greatest degree must be looked on, when in connexion with lead, as the most dangerous.

After making a series of experiments I find that water which derives its hardness chiefly from supercarbonate of magnesia is more dangerous than water which altogether or in greater part derives its hardness from supercarbonate of lime. I find then that the following salts of hard water are capable of dissolving the hydrated oxide of lead. They are placed in the order of their solvent power, and consist of Mr. Spencer.

Supercarbonate of Magnesia.
Supercarbonate of Lime.
Chloride of Sodium.
Chloride of Magnesium.
Chloride of Calcium.

As it may be necessary to verify these results by some readily made experiments requiring little chemical experience, I subjoin the following:—

Make a hydrated oxide of lead, by dropping its acetate (sugar of lead) into a solution of ammonia. The resulting powder is the oxide, and represents that which is formed by atmospheric action in water. Let it be washed until the water shows no indications of lead by sulphuretted hydrogen. A few grains of the oxide thus formed are to be put, while moist, into a bottle containing a few ounces of what is termed fluid magnesia (sold in the shops as Sir James Murray's fluid magnesia). It may be diluted with half or four or five times its bulk of water, its solvent power being in the ratio of its strength. After agitation for a few minutes let it be filtered, and when the usual tests are applied to the filtrate of magnesian water, it will be evident that the oxide of lead has been dissolved.

This fluid magnesia is chemically identical with the supercarbonate of magnesia found in hard water; the simple carbonate being in both cases held in solution by carbonic acid. This experiment shows the solvent power of magnesia when found in hard water.

Another experiment may be made to prove that the supercarbonate of lime also dissolves this oxide. To do so it is only necessary to repeat the foregoing one, but substituting carbonate of lime-water for the magnesian. That sold in the shops as "Carrara Water" (being carbonate of lime held in solution by carbonic acid) precisely represents the carbonate of lime which is found in hard water.

Upon applying the test as before, it will be found that this also dissolves the oxide, but less so than in the preceding instance.

The free carbonic acid, which is to be found in these artificial waters, does not contribute to these results, for should it combine with the oxide the resulting carbonate is insoluble.

An experiment may also be made with common salt (chloride of sodium) dissolved in water, or with chloride of calcium or of magnesium, and, when the test is applied, the oxide will be found in chemical solution; but in these cases sparingly.

The salts which I have enumerated are contained more or less in all potable hard waters. When, therefore, it can be satisfactorily proved that their action upon the oxide of lead is such as I have found it to be, the system of storing up water in open leaden vessels ought to be discontinued. With us, in Liverpool, we have hard waters in public use which contain as much as from 20 to 40 grains of

Mr. Spencer. these substances to the gallon, while many private wells contain from 100 to 200 grains in the same quantity of water.

I am fully convinced that the proportion of air which is naturally contained in either hard or soft water contributes little practically to the formation of either the oxide or carbonate of lead. Where I have made experiments with fresh-caught soft water, and therefore containing its full proportion of air, little or no action has been observed on slips of lead when immersed in it. It is important, however, to bear in mind, that this has only been so when I have taken the precaution to cover the surface of the water with oil, thus rendering further access of air from the atmosphere impossible. Where I have neglected to adopt this precaution, the oxide formed, be the water hard or soft.

I have not found that others have had recourse to this plan of excluding the air during their experiments, otherwise I think it probable that it would have had some influence in modifying their results. I find also, upon much inquiry, that, wherever a constant supply of water is given, little or no signs of corrosion are manifested upon the interior of the leaden service-pipes, they being kept always full, and necessarily free from air.

It is well known that a highly comminuted powder of metallic lead may be made to become mechanically diffused by agitation throughout either hard or soft water: and while in this state it most readily attracts oxygen.

Where I have agitated pieces of lead in water deprived as much as possible of air, the bottles being also perfectly filled with water, this powder has not been formed so copiously. That the atmosphere exercises a main influence in diffusing lead, will be further evident, when we take into consideration that this metal is to some extent volatile, it being known to impart a peculiar odour, which is abundantly evident upon its being handled.

In conclusion, I may state generally that I have not been able to detect lead in ordinarily soft water which had passed through pipes which have been kept always full, and consequently free from atmospheric exposure.

Abstract of the Foregoing.

When lead and soft water act upon each other in perfectly close vessels or pipes, it is due in all ordinary cases to that air which water may be said to contain naturally.

When this action takes place, it never extends beyond a slight formation of a low oxide of lead, *which is insoluble in soft water.*

Where an oxide is extensively formed, it is due to the extraneous absorption of air from the atmosphere, but which can only occur when the surface of the water is exposed, as it is in a cistern.

We thus deduce, as a direct consequence, that leaden pipes, when kept charged with water, are little objectionable, inasmuch as they are then comparatively free from atmospheric action. In practice it is also found that leaden service-pipes which are kept full, as in a constant supply they must be, exhibit little or no traces of oxidation after long use.

As it is obviously impracticable to keep cisterns always full, as well

as it is to keep them free from the operation of the atmosphere, it would therefore follow that their use is highly objectionable for either hard or soft water. Mr. Spencer.

The following applies more particularly to *hard water*.

When hard water is exposed to the atmosphere in an open leaden cistern, the hydrated oxide of lead and its carbonate are more rapidly formed than in soft water; the evaporative action upon the moist sides of the cistern, much promoting the formation of these substances.

In the vicinity of the soldered parts of a cistern, however, the oxide is still more rapidly produced, in consequence of the voltaic action which takes place where dissimilar metals are present, the superior electrical conductive power of *hard water* promoting the action. Hence it is that cisterns which contain hard water corrode so rapidly at the joints.

When decayed organic matters accidentally fall into a cistern, hard water also acts more injuriously than soft. It is well known that water holding any substance in solution is more easily decomposed than purer water. In such a case water is decomposed, and carburetted hydrogen is given off, whilst the resulting oxygen enters into combination with the lead. Holes are thus frequently found at the bottom of cisterns where such matters have rested.

When oxide of lead is formed in commonly pure or soft water, it *is not soluble, yet hard water is capable of dissolving it.*

It becomes thus diffused chemically throughout the volume of water. It may therefore be said, as regards lead, that water is dangerous in the ratio of its hardness.

All hard waters, however, are not equally capable of dissolving this oxide, their solvent power depending on the character of the salts which they contain. For instance, water which contains carbonate of magnesia in solution has a higher solvent power than that which contains an equal amount of carbonate of lime. In like manner chloride of sodium (common salt) dissolves this oxide of lead more readily than the chlorides of magnesium or calcium.

I have the honour to be, Sir,

Your very obedient servant,

THOMAS SPENCER.

Henry Austin, Esq.,
Gwydyr-House, Whitehall.

Liverpool, 9th May, 1850.

LEAD PIPES.

"THE subject of lead pipes has lately attracted much attention in Boston, where the matter was fully investigated previous to their adoption, in distributing the Cochituate water, recently introduced into that city. The result of the investigations, conducted under the superintendence of Professor Horsford, has recently been published in the Report of the Water Commissioners, and sets the question, in my opinion, finally at rest. From this Report it appears that no evidence of disease from lead has yet been detected in the cities of London and Paris, from the use of the hydrant water, although that material is in universal use in both of these cities as service-pipes." Dr. Wynne.

"Professor Hare of Philadelphia, Professor M'Naughton of Albany, and Dr. Bruismade of Trov, New York, all bear testimony to the

Dr. Wynne. same fact, although the lead for service-pipes has long been used in each of these towns. Professor Hubbard of Dartmouth College, states that the village has been supplied for 26 years with water conveyed two miles in lead pipes, and that he has never heard of a case of lead poisoning from its use."

"Dr. Dana, in an Appendix to his Translation of the Work of M. Tanquerel, on lead diseases, recently published, has furnished a very strong argument against the use of lead pipe, which, in the absence of the positive testimony furnished by the Boston Water Commissioners' Report, might go far towards banishing it from use. In his remarks on the specimens of Baltimore and James River pipes examined by him, he says that he observed slight cribriform erosion, and adds, "But this is evidence that so slight an action could not have been sufficient to produce erosion in a few days. It may be inferred to have gone on for years." Since the appearance of Dr. Dana's work, I have examined numerous specimens of lead pipe, which has been long in use in Baltimore, some upwards of 25 years; and although I have anxiously sought for some evidence of the slight erosion mentioned in Dr. Dana's work, I have not, in any instance, been able to detect it. I therefore conclude that the erosion in the specimen examined by him was due rather to some original defect in the texture of the metal, than in the action of the water upon it. The interior of the pipe was always found thickly coated with an earthy deposit, which adhered with such tenacity as to require considerable force and much washing to remove it, and in my judgment formed a considerable protection to the water against the action of the lead, admitting its capacity to unite with the water which did not appear, from any evidence, furnished by the pipe itself.

"I have met with several cases of disease from lead amongst workmen engaged in its manufacture since my residence here; but have never observed any lead disease which might be attributable to the use of the hydrant water. Within a few weeks, the pipe of the hydrant attached to my own residence was removed, and its place supplied by a new one at least 60 feet in length, and although the water was used soon after, I could not learn that any member of my family experienced the slightest injury from it."—*From a Report on the Sanitary Condition of Baltimore, by James Wynne, M.D., published by the American Medical Association.*

Thomas Clark, Esq., M.D., Professor of Chemistry in Marischal College, University of Aberdeen, examined.*

Professor Clark, M.D. 1. You are professor of chemistry at Aberdeen?—I am.

2. It is stated that you have paid much attention to the quality of water in the metropolis and other parts of the United Kingdom; is that the case?—I have paid attention to this subject for many years, partly from the interest to society that belongs to the subject of the supply of towns and manufactories with good and wholesome water,

* This evidence, which was originally taken on the 3rd June, 1843, by the Commissioners of Inquiry into the State of Large Towns and Populous Districts, has been revised by the witness. The principal additions are distinguished by brackets.

and partly also from the interest that belongs to the subject as a branch of knowledge, and a part of my duty in teaching pupils at the college. I have examined very particularly the qualities of the waters most in use in the metropolis, and in several other towns throughout the United Kingdom, but not the waters of a great many towns. Professor Clark, M.D.

3. What are the various kinds of impurities found in water?—These are of various kinds. There are the mineral or saline, the vegetable, the animal, and also the mechanical impurities.

4. What kind of impurities are separated by filtration?—Only the mechanical. (See Q. 41, 44, 45, 48, 52, 64, 65.)

5. You have stated that the water usually contains saline impurities; of what do those consist?—The most material are earthy salts, that is, salts of lime, and salts of magnesia. I call the earthy salts the most material, because it is the presence of earthy salts that gives rise to hardness. There is also usually present common salt, and sometimes bicarbonates of soda and of potash; but none of these affect the hardness of water. The most important portion of the earthy salts may be reckoned the bicarbonate of lime. The whole salts present, whether earthy or not, may be distinguished into two parts, according as they are neutral to test paper, or alkaline to test paper, (See Q. 18.) the neutral portion and the unneutralized portion. The unneutralized portion consists entirely of bicarbonates, those of lime and of magnesia, which are the earthy bicarbonates, and in some waters those of potash and soda, which are the alkaline bicarbonates. The neutral portion consists of the neutral salts of earths and alkalies, such as gypsum and common salt. Salts of iron occur also occasionally in waters that are in use. Such salts impart an inky taste to the water, and they give a yellowish tint to linen that is washed by the water containing them. They, too, produce hardness.

6. What are all the impurities in water that give rise to the quality commonly termed hardness?—The earthy salts and iron salts, if they be present; certainly earthy salts are the principal cause. I have had occasion to observe recently that there is in a few waters a minor cause, carbonic acid, where it exists in excess; that is, in a greater quantity than is sufficient to form the bicarbonates present.

7. Does boiling, exposure to the air, or filtration, affect the hardness of water?—Filtering does not affect the hardness of water. Exposure to the air softens waters so far as they are hardened by carbonic acid, and it very slightly affects waters that are hard on account of earthy bicarbonates. Boiling affects the hardness of waters in some cases; it does not affect it at all in others. Boiling softens very materially such water as contains earthy bicarbonates, by decomposing them; but so far as the earthy salts are neutral, it does not affect the hardness at all. As the operation of boiling is usually conducted, indeed, according as the hardness is owing to an unneutralized earthy salt or to a neutral earthy salt, the effect of boiling may be the reverse; that is to say, if you boil water containing an unneutralized earthy salt, you soften it; if you boil water containing a neutral earthy salt, you harden it, in case you concentrate the water by letting part of the water, pure and perfectly soft, escape in the form of steam. Therefore it is a most material point in the treating of water to be aware, not only of the amount of its hardness, but how far that hardness is due to neutral earthy salts, and how far to unneutralized earthy salts.

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8. Is not there a testing process of easy application by which the hardness can be measured, and by which the hardness affected by boiling can be distinguished from that not so affected?—There is a very easy and most accurate process for trying the hardness of water, that I had occasion to contrive above two years ago. I need not go into the details of that before the Commissioners, because the details of the method are printed in a specification to a patent of mine, dated the 8th of March, 1841. The specification is printed in the Repertory of Patent Inventions for October, 1841.* All I need state at present in reference to that method is, that you can try by it the hardness of water in the course of less than an hour. The method I take of expressing the hardness of water is this, 16° of hardness means the hardness that would be caused by the presence of 16 grains of chalk per gallon; 10° of hardness, the hardness that would be caused by the presence of 10 grains of chalk per gallon. In the application of this process, it is of no consequence in what state of combination the earthy salts be. Whether the lime or other earth present be in the state of bicarbonate, or in the state of a neutral salt, or in both states, the test would indicate precisely the same degree of hardness in any two waters, if the quantity of earth, or of basis of the earth in each, were present in the same proportion. There is also a test given in the process alluded to for distinguishing so much of the earthy salts present as are neutral, from so much of them as are unneutralized, that is alkaline, or in the state of bicarbonates. (See Q. 25.)

9. It is generally admitted that hard water (See Q. 12, 31.) is unfit for the purposes of washing and of cooking?—With regard to cooking, perhaps the most important material is tea. I have been very desirous of making a series of experiments on waters of known degrees of hardness upon a given average of tea, with the assistance of some gentleman experienced in the tasting of teas for commercial purposes. My health has heretofore prevented me from making any more than merely preliminary experiments. From these it appeared that hard water was very unfit for the purpose of infusing tea. In making use of a series of waters at 4°, 8°, 12°, 16° of hardness, the strength of the infusion, as manifested by the depth of colour produced, was evidently in a series, such that each infusion could be sensibly distinguished from the one next to it, above or below, the hardest water giving the least depth of colour, and the softest water the greatest. At 4° of hardness the infusion was transparent with no sensible muddiness; at 6° the transparency of the infusion began to be injured; at 12° there was a distinct muddiness; at 16° this muddiness had become very decided, and above 16° it was disgusting. No such muddiness appeared with any of the waters after pouring off the first infusion and making a second. With regard again to depth of colour, it is very worthy of remark that, whereas the greatest depth was observed in the first infusion in the softest water, and the least depth in the hardest, now, in the second infusion the same thing was observed again, with this difference, that in the harder waters the depth of colour was proportionally still less; not only absolutely less, as might be expected, but relatively less. In making these experiments, about half an ounce of tea was made use of with a pint of boil-

* Republished by J. J. Griffin and Co., Baker-street, who also prepare the apparatus and tests necessary.

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ing water, so that you will understand the result, if you suppose in each of two similar teapots half an ounce of tea be put, and over each a pint of boiling water, but in the one case at 4° hardness, and in the other case at 16°, the infusion at 4° will turn out much stronger than the infusion at 16°; the infusion at 4° will be transparent; the infusion at 16° will be offensively muddy. But supposing you pour off the first infusion and make a second infusion, then the second infusion at 4° will be a little weaker in colour than the first infusion at 4°, while the second infusion at 16° will be of a still proportionally weaker colour than the first infusion at 16°. In short, hard water is bad for a first infusion, still worse for a second. The only way of making an infusion of tea with waters at 8°, 12°, or 16°, equally strong with an infusion by water at 4°, is to increase in each case materially the quantity of tea infused. Sub-carbonate of soda in crystals may be made use of in very small quantities in order to soften the water and make it fitter for the purpose of infusing tea; it produces this effect by decomposing the earthy salts present; but if made use of in any proportion above what will exactly decompose the earthy salts present, the excess may indeed deepen the colour of the infusion—by dissolving some coloured vegetable extract, such as pure water, would not dissolve, but it will infallibly injure the fine flavour of the tea to all persons not accustomed to the taste of soda in their tea.

10. Is there any other respect in which the hardness of water is injurious to the inhabitants of towns?—The fur (which is an incrustation chiefly of chalk) that forms when waters that are rendered hard by the presence of an earthy bicarbonate are boiled, is at least exceedingly inconvenient. In all the manufactories in large towns, so far as you have got such a water, the bottoms of your steam-engine boilers become incrusted very soon. This requires the steam-engine boilers to be cleaned out much oftener; and I think that the fur formed by such a water is the most frequent cause of explosion in steam-boilers, and most materially increases that risk; at the same time that it causes the wear and tear of them to be much greater. Fur likewise very much increases the risk of explosion in locomotive engines. I think also that fur must be very inconvenient, whenever you attempt to heat by water-pipes, because, immediately on employing such water the pipes get coated internally with earthy matter, in some cases to a very material thickness, so as to fill up the metallic pipe with an earthy incrustation, and prevent the heat from passing through. I have known pipes connected with boilers, in a large brewery in London, filled up throughout the whole length by a solid incrustation in six months.

11. What conditions in water do you think fit it best for being an agreeable beverage?—In the first place, the particular kind of water that is agreeable is dependent very much upon the habits of the drinker. If you are accustomed, exclusively, for a certain time, to a hard water, you acquire a liking for hard water; if to a soft, you acquire a liking for soft, just as habit varies the taste for other beverages. Putting the effect of habit out of the question, one circumstance, which I think is most material for water to be agreeable, is the temperature, especially in warm weather, when good water to drink is most prized. It has been supposed that water, such as is used in this town, being exposed in a

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room for some time loses a portion of carbonic acid. Everybody knows that water which has been in a sitting-room is not so agreeable as when first drawn; but I am quite satisfied that whatever be the cause of its becoming less agreeable, it is not in general the loss of carbonic acid; for I am quite certain that there is not in any of the river waters about London an excess of carbonic acid over and above what is necessary to form the bicarbonates present. I think the main point affecting the agreeableness of water, as far as I have seen in examining water accounted agreeable in this town, is the temperature. In summer time you have the spring waters, when fresh drawn, cool. You can have other waters rendered more agreeable than they are in summer time, if you take the pains of cooling them to the same degree as the spring water. You must not have the water too cool either, otherwise it is unpleasant, as well as unsafe to drink, but an average temperature of the climate, which is about 50° Fahrenheit, is a very agreeable temperature for water. So far as the presence of carbonic acid will add to the agreeableness of water, and it does so to many tastes, that quality can be imparted to any water by the simple expedient of adding a very small proportion of soda water. No doubt there are circumstances that make water offensive, particularly the presence of vegetable matter in a state of change, whether that matter be undergoing putrefaction, or a vegetating process of any kind. In any such case I reckon the water polluted, and the taste is entirely tainted and offensive, especially to persons not accustomed to drink such water. But if water be free from taint, be of a sufficiently low temperature, and be not absolutely deprived of wholesome gaseous matter, I think it has most of the qualities proper to render it agreeable, allowing for the variations in taste that are acquired. If all these conditions contributing to the agreeableness of water exist, then I think that such persons as have been accustomed to drink various kinds of water will be found to prefer a water containing little saline matter to another containing much; if a contrary impression has been usually entertained, it is owing to some of the other circumstances affecting agreeableness having been overlooked. At the present time, in order to obtain good water for drinking in London, I would recommend the use of water that has been boiled, cooled, treated with carbonic acid by the addition of a little soda water, and then iced to a temperature rather under 50° Fahrenheit; but all this pains to obtain good water cannot be taken by the poor, or even by the generality of families in the middle classes. I think that if the means were taken by the existing water companies, water only requiring to be a little cooled in the heat of summer to be fit for drinking by all classes, might be supplied, and should.

12. What general circumstances would regulate you in the choice of a water for the supply of a town?—There is a great variety of circumstances to be taken into account in selecting a water for the use of a town. Supposing we had the choice of several waters, there is no single quality of a water to which I would attach more importance than softness, because, although a soft water may not happen in other respects to be agreeable for drinking, yet it very often happens that water agreeable enough for drinking is supplied by wells in the town. The proportion of the whole supply of water used by the inhabitants for drinking is exceedingly small; for this reason, the mere agreeable-

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ness of the water as a drink, I would not reckon a high point. With regard to the softness of water, this quality is of importance, not merely for the saving of soap to households, for the agreeableness of washing at the toilet, for the agreeableness and utility of bathing, which I account a most important practice for promoting the health of the inhabitants of a town, but also in respect of the wear and tear of linen due to hard water. Such wear and tear comes to be a very large item of expense to the inhabitants of a town. The inhabitants of London are probably not aware so much as visitors from the country are, of the amount of destruction to clothes in consequence of the hardness of the water, and the use of soda in order to get rid of the hardness. I remember an occasion, which I may mention, where the amount of wear and tear was brought out in a very conspicuous manner. Two young men, brothers, in Glasgow, were put into counting-houses, one in London and the other in Glasgow. They had each a similar assortment of shirts given to them. Some time after, when the brother in London came back on a visit to Glasgow, the lady of the house pointed out, to the wonder of her female friends, the difference there was in the wear of the shirts of the two brothers, that had been given at the same time; those that had undergone the London washing were so much more worn than the others which had been washed at Glasgow. Yet I can state from experience that linen gets soiled from the atmosphere rather more readily in Glasgow than in London.

13. What was the difference in the hardness of the water?—The hardness of the Glasgow water was about 4° and that of the London about 12°.

14. It is to be assumed that a great saving would accrue to a town by using soft water, in the article of soap, for instance?—Not only in the article of soap, but probably much more in the saving of the wear and tear of clothes. The hard water has a tendency to discourage washing of clothes among the poorer classes, and to bring on them greater expense in clothes. This consideration bears very closely on the clothing of women and children; and I rather think, that if manufacturers of the articles of clothing worn by women and children, in a district supplied with hard water—this very London, for example—were consulted, it would appear that they are obliged to supply articles of such dark dyes as will not let the dirtiness be seen. Now to substitute the art of concealing dirt for a habit of cleanliness, not only is unfavourable to health and comfort, but is unfriendly to a decent self-respect; yet an observant eye cast on the women and children of the poorer inhabitants of London, may discover that such has been the result here.*

15. What degree of hardness do you think would render water unfit for the use of a town?—That is a question that cannot be answered definitely. Of the waters used in towns, I am not acquainted with a great number. The pipe water that I am accustomed to use at home stands at only 1° of hardness; meaning thereby, as was mentioned before,

* "We returned to the beautiful St. James's Park, went through the Green Park to Hyde Park, then into Kensington Gardens, and back to Hyde Park, favoured by the weather, and cheered by the freshness of a spring. * * * * * All the women of the lower classes were very simply dressed, *chiefly in black or dark colours*, but few remarkable for beauty."—See Raumer's "England in 1835," vol. i., p. 212.

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(see Q. 8) as much hardness as the presence of one grain of chalk per gallon would produce. The pipe waters of London range between 11° and 16°, according to my experience; I mean the waters of the companies. The pipe water of Manchester is 12° of hardness; the water of Glasgow is 4½° of hardness; of Edinburgh about 5°; the Newcastle-upon-Tyne Company's water is nearly the same, according to a single trial, taken however after much rain. With regard to the general question, what degree of hardness should unfit a water for being used, that is manifestly a question that cannot be answered absolutely. The softest water that can be got in sufficient quantity *in the district*, I hold to be in general the one that ought to be preferred, other circumstances being favourable. I think, from observing (and I have given a good deal of attention to such observations on the action of water) that a water ceases to be agreeable for washing when it is above 4° or 5° of hardness; I have already mentioned that a harder water than this is very objectionable for the making of tea. (See Q. 9.) Water, when it is above 16°, I would say becomes excessively inconvenient for washing. There are some hard waters more objectionable than others, even of the same degree of hardness, on account of the curdy or clotty character of the earthy soap produced in them. This clotty character renders such waters particularly unfit for the washing of clothes. Now, I find this character of hard water to be due to the presence of a little magnesian salts. And it is a very curious fact, that if the hardness of the water be above 10° or 12°, owing to lime salts, a few degrees of hardening matter in the form of magnesian salts may be added to the water, without its hardness being increased; but then the curdling power of the water is very much increased. There are, however, waters much harder than 16° in use, and those, undoubtedly, must be accounted fit waters for use, provided they are the softest that can be got in the district.

16. To what district do you refer, where there are very hard waters? —Paris might be mentioned as one instance. Many towns in England also are unfortunately supplied with harder water than 16°.

17. The pipes or leaden cisterns are sometimes corroded by water, what is the particular impurity which occasions that corrosion?—I think both leaden cisterns and pipes, and iron pipes, are corroded occasionally by water. This is a most important topic, because it has happened in some places that a water has been selected for the supply of the inhabitants, and an expense of erecting water-works gone into, and corrosion quite unexpectedly has been the result. A variety of investigations have been made as to the cause of this important objection to some waters. In considering published investigations and some observations that I have made upon the subject, I should be disposed to say, that chemists are not prepared at present to speak with much confidence as to the cause. My present impression, and indeed the prevailing impression, is, that the corrosion is due to free carbonic acid. It is well known that distilled water acts very readily upon lead. The cause of this action I apprehend to be the remarkable power that distilled water, compared with ordinary water, has of dissolving free carbonic acid.

18. By free carbonic acid you mean carbonic acid above what is necessary to form bicarbonate with the other salts?—Yes; I would add, however, that I believe that carbonic acid in excess will be found most

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frequently where there is either no bicarbonate, or next to no bicarbonate present. If I obtain a water for examination, the first point I look to is, whether this water has an alkaline action; that is, whether it contains any bicarbonate. This is done by litmus test-paper. If the test-paper is not rendered of a blue tint by the water, so as to show an alkaline salt present, the chance is, that the test-paper will show, and very explicitly, the presence of carbonic acid, by the redness produced upon it. There is one water of this description supplied to the hospital at Bagshot, where, according to my information, for I have not inspected the case, a mile of iron pipes were corroded in a remarkably short time. This water as it came from the spring had a considerable excess of carbonic acid, and stood about 6° hardness; when freed from this excess it stood rather under 3°. The principal peculiarity I have as yet been able to observe in the water is, the almost entire absence of bicarbonate, and I have also observed the presence of free carbonic acid to be very frequent in waters that contain very little, if any, bicarbonate. In general, an alkaline water will not act upon lead or upon iron. But perhaps I should not say in general, for I have not examined a sufficient number of cases to lay down a general rule; but there is ground for suspecting that such an action will ensue, if you find in the water a very moderate degree of hardness and no alkalinity, together with an excess of carbonic acid. In making these statements I would still repeat that I do not consider myself entitled to speak with great confidence as to the cause of the corrosion of pipes in every case. (See Q. 71, 72.)

[At the time of answering the foregoing questions respecting the action of water upon lead pipes, I had not had the opportunity of examining any water that had been contaminated by lead pipes; but in a few days after, an opportunity occurred. Some of the Bagshot water alluded to had poisoned some of the Queen's hounds, and brought on *colica pictonum* on one of the huntsmen. Through the kindness of Sir James Clark, I obtained a specimen of this water, and in a few days came to the unexpected result that filtration would separate the lead. Thus a very simple practical means for separating lead, wherever it contaminates water, was discovered. On the 5th August, the same year (1843), being about to leave London, I left a memorandum with Sir James Clark, that I was ready to provide against the ill effects of the lead, if applied to by any authority connected with the palaces. No application was made to me. But the process came into practical use in spring 1844. At a marine villa of Lord Aberdeen's, some of the servants suffered in health from lead in water derived from pipes. Sand filters were put up under my direction at this villa, and subsequently at Haddo House. On making inquiry recently, at his Lordship's agent, in Aberdeen, I learn that the filters have been in use ever since, and that the waters have been tested from time to time, without any lead having been discovered in them. I have been told indeed, that so satisfied has Lord Aberdeen been with the result, that on hearing of the Count de Neuilly's family at Claremont, being troubled with lead in the water, he wrote recommending the same process being tried there; and from general rumour I had previously heard that the process had been adopted there. I hope I may be excused for entering into such details, for the indication they afford of the practical value

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of the process which has been adopted in the public service, without the merit of the inventor having been publicly recognised or acknowledged.

I hold it in all cases to be dangerous to allow water to pass through any considerable length of lead pipes, or to allow water to remain for a long time even in short pipes. In the case of the marine villa before alluded to, the water came a considerable distance through lead pipes; I suppose above a quarter of a mile. The water in Aberdeen is brought from the iron mains in the streets, into the houses by means of lead pipes; and in general without any disadvantage, because the supply from the pipes is constant, and the use of the stop-cock very frequent in a family; but in my class-rooms and laboratory I find that whenever a pipe has been out of use for a few days, the water taken from it affords a trace of lead, which disappears when the water has been allowed to run briskly from the stopcock for a few minutes.]

19. Under what circumstances does chalk, or carbonate of lime, dissolve in water?—The solvent of chalk in water, as it commonly occurs, is carbonic acid; and the chalk is present as bicarbonate of lime; and in the rivers that supply water to London, I have not yet found more carbonic acid than is required to form such a bicarbonate. Indeed, there is a circumstance that shows manifestly that a received idea that river water contains free or uncombined carbonic acid, is not correct. You cannot keep exposed to the air a water, such as that of the Thames, for a few days, but a small deposit of chalk will occur. The first occurrence of that deposit is a proof that there cannot be present any excess of carbonic acid. Besides this, I have repeatedly ascertained by conclusive experiments carefully performed, that the river waters about London do not contain any sensible excess of carbonic acid.

20. Can you state the quantity of carbonate of lime, or the degrees of hardness of various known waters, and the degree to which they may be softened by the application of artificial means?—I shall lay before the Commissioners some statements relative to the waters of the metropolis. Take the New River. In the middle of May, 1841, I found in the New River $13\frac{2}{10}°$ of hardness per gallon.

21. From what part had you the water of the New River taken when you made the experiment?—This particular specimen was taken out of the New River itself; it was several gallons, probably from 20 to 30, sent to me to Aberdeen for the purpose of subjecting it to experiments. The next is the result of a great variety of trials I made from day to day of the New River water, collected by me while in town, from the pipes, taking them from various places, and finding no material difference. At the beginning of August, the same year, I found the hardness 12°.

22. Those were all New River waters?—Yes. The Thames in the middle of May, 1841, I found $14\frac{4}{10}°$ of hardness; this was a large specimen taken opposite Mortlake.

23. Do you know what was the state of the tide at the time it was taken?—I cannot answer particularly, but I remember the collection was committed to a very careful gentleman, with all the precautions that I thought at the time necessary; I do not remember what they were at this moment. I believe I bade him take the specimen imme-

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diately after the turn of the tide. The river at Mortlake is above the influence of the London sewerage. In the beginning of August, from a very great variety of trials that I made from the waters collected from various pipes in town, I found the hardness of the Thames water $11\frac{8}{10}$°. The East London Company's water was $16\frac{1}{10}$° in the middle of May, 1841. This was a large specimen, which the engineer, Mr. Wicksteed, was good enough to forward to me to Aberdeen, at my request. The same company's water, taken from the pipes at the beginning of August, was $14\frac{1}{10}$° on an average, in a variety of trials.

24. The degrees of hardness will vary at different times, one or more?—The variation here, I take not to be due to the method of testing the specimens, but to the state of the weather, and also to lengthened exposure, which probably softens water two or three degrees.

25. Have you notes of the hardness of any of the waters on the Surrey side?—On the 11th of August, 1841, the Vauxhall Company's water was $13\frac{5}{10}$°.

26. How do you distinguish what is due to neutral earthy salts, and what to alkaline earthy salts?—By the soap test referred to (See Q. 8.), the total hardness can be ascertained, that is, the hardness due both to neutral and to alkaline earthy salts. Next by the test acid, which is described in the specification referred to, we can distinguish the portion of the hardness that is due to alkaline earthy salts; for instance, East London water, collected on the 14th of May, 1841, is of hardness $16\frac{1}{10}$°; it is of alkalinity $15\frac{6}{10}$°; that is, it requires as much acid to neutralise its alkalinity as $15\frac{6}{10}$ grains of chalk per gallon would require; the difference, $\frac{5}{10}$° is the utmost quantity that can be due to neutral earthy salts. The Thames water and the New River water may in general be reckoned 12° of hardness; the alkalinity in the London pipe waters almost always comes within 1° of the hardness, whereas the Manchester pipe water stands 12° of hardness, while its alkalinity, according to my recollection, is only 7°. Hence, in the Thames or the New River water, no more than 11° can be regarded as the hardness due to alkaline earthy salts, and no more than 7° as the hardness due to alkaline earthy salts in the Manchester water. On boiling the Thames water, therefore, you soften only by acting on 11° of hardness, and on boiling the Manchester water yon soften only by acting on 7° of hardness.

27. It is understood that you took out a patent for purifying water, by removing the carbonic acid which holds the earthy carbonates in solution; will you describe the general nature of your invention?—I beg the permission of the Commissioners to read the following extract, containing an outline of the process:—"To understand the nature of the process, it will be necessary to advert, in a general way, to a few long-known chemical properties of the familiar substance, chalk; for chalk at once forms the bulk of the chemical impurity that the process will separate from water, and is the material whence the ingredient for effecting the separation will be obtained. In water, chalk is almost or altogether insoluble, but it may be rendered soluble by either of two processes of a very opposite kind. When burned, as in a kiln, chalk loses weight. If dry and pure, only nine ounces will remain out of a pound of 16 ounces. These nine ounces will be soluble in water, but

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they will require not less than 40 gallons of water for entire solution. Burnt chalk is called quick lime, and water holding quick-lime in solution is called lime-water. The solution thus named is perfectly clear and colourless. The seven ounces lost by a pound of chalk on being burned consist of carbonic acid gas; that gas which, being dissolved under compression by water, forms what is called soda-water. The other mode of rendering chalk soluble in water is nearly the reverse. In the former mode, a pound of pure chalk becomes dissolved in water in consequence of losing seven ounces of carbonic acid. To dissolve in the second mode, not only must the pound of chalk not lose the seven ounces of carbonic acid that it contains, but it must combine with seven additional ounces of that acid. In such a state of combination chalk exists in the waters of London, dissolved, invisible, and colourless, like salt in water. A pound of chalk, dissolved in 560 gallons of water by seven ounces of carbonic acid, would form a solution not sensibly different, in ordinary use, from the filtered water of the Thames, in the average state of that river. Chalk, which chemists call carbonate of lime, becomes what they call bicarbonate of lime, when it is dissolved in water by carbonic acid. Any lime-water may be mixed with another, and any solution of bicarbonate of lime with another, without any change being produced. The clearness of the mixed solutions would be undisturbed. Not so, however, if lime-water be mixed with a solution of bicarbonate of lime. Very soon a haziness appears; this deepens into a whiteness, and the mixture soon acquires the appearance of a well-mixed whitewash. When the white matter ceases to be produced it subsides, and, in process of time, leaves the water above perfectly clear. The subsided matter is nothing but chalk. What occurs in this operation will be understood if we suppose that one pound of chalk, after being burned to nine ounces of quick-lime, is dissolved, so as to form 40 gallons of lime-water; that another pound is dissolved by seven ounces of extra carbonic acid, so as to form 560 gallons of a solution of bicarbonate of lime; and that the two solutions are mixed, making up together 600 gallons. The nine ounces of quicklime from the one pound of chalk, unite with the seven extra ounces of carbonic acid that hold the other pound of chalk in solution. These nine ounces of quicklime and seven ounces of carbonic acid form 16 ounces, that is, one pound of chalk, which being insoluble in water becomes visible at the same time that the other pound of chalk, being deprived of the extra seven ounces of carbonic acid that kept it in solution, reappears. Both pounds of chalk will be found at the bottom after subsidence. The 600 gallons of water will remain above, clear and colourless, without holding in solution any sensible quantity either of quicklime or of bicarbonate of lime. The weight of chalk separated from the whole waters of the several Companies, estimated at 40 millions of imperial gallons, would be about 24 tons a-day, or 9,000 tons a-year. Here the weight stated refers to matter such as no filter can separate, and it does not include any of the precipitated chalk that has for its basis the lime added to the water in the form of lime water. Taking both together, the chalk that falls down would amount to 55 tons a-day, or 20,000 tons a-year. As far as I have been able to ascertain, the cost of the burnt chalk required for all the water Companies in the metropolis would be 10*l.* a-day. Against this cost may come

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to be deducted the value of the 55 tons a-day of deposited chalk, which cannot but be available for some useful purposes. Being burned it would afford lime of improved quality for mortar, and without being burned it might answer as an ingredient of compost manures for clay soils. At the least, the expense of the burned chalk would be reduced to the cost of burning."*

28. Can you give the results as to the degrees of hardness and alkalinity removed by the application of your process?—In the case of the East London water, I found the hardness $16\frac{1}{10}^\circ$, the alkalinity $15\frac{6}{10}^\circ$. It may be interesting to mention, that having kept the water for a long time in open vessels in a large laboratory, the hardness fell to $15\frac{4}{10}^\circ$. By mixing the water of $16\frac{1}{10}^\circ$ of hardness with lime-water, in the proportion of four bulks of lime-water to 44 of the original water, I found the hardness reduced to $4\frac{1}{10}^\circ$. In another trial, in the proportion of 4 to 45, the hardness became 4°. In subsequent trials, when the hardness of the water was 15°, I found the purified 4°; when the hardness was $14\frac{2}{10}^\circ$, the purified was 4°. In one case, when the hardness was $14\frac{4}{10}^\circ$, the purified was $3\frac{8}{10}^\circ$. The general result was 4° of hardness in the purified East London water. Connected with this water, I may mention that all water holding carbonate of lime is softened by prolonged boiling; there is a misapprehension, however, in regard to the effect of boiling; a short boiling has very little effect indeed in softening water; when you subject water to even a sharp boiling, under the most favourable circumstances, I find two hours and three quarters, or three hours, necessary for decomposing all the bicarbonate of lime, precautions being taken to prevent any evaporation of water in the form of steam. By boiling, this water was reduced to $3\frac{7}{10}^\circ$. In the case of the New River water the hardness was $13\frac{2}{10}^\circ$, the alkalinity was $12\frac{5}{10}^\circ$; this purified by lime-water, in the proportion of 3 to 40, was reduced to $3\frac{7}{10}^\circ$ of hardness; by prolonged boiling it was reduced to $3\frac{6}{10}^\circ$ of hardness. I got another specimen of New River water, $11\frac{6}{10}^\circ$, which, by using the proportion of 1 of lime-water to $14\frac{5}{10}^\circ$ of the water, was reduced to the hardness of $2\frac{6}{10}^\circ$.

29. Can you give any account of the degree of softness acquired by the London pipe waters when boiled, as is usually practised for household use?—In the summer of 1841, I had the curiosity to make several trials of the hardness of boiled New River water; the following table presents the results:—

			Hardness.
1841.	May	Tavistock Hotel, Covent-garden	7°·1
,,	July 31	The same	6·0
,,	Aug. 1	The same	7·4
,,	Aug. 2	The same	5·2
,,	Aug. 4	The same	4·8
,,	Aug. 16	Bedford Hotel, Covent-garden	2·9
,,	,,	Hummum's Hotel, ditto	6·8
,,	,,	Private family, ditto	3·0
,,	,,	Private family, Charlotte-street, Bedford-square	4·0

At University College a large boiler of water, being kept heated for

* A new Process for purifying the Waters supplied to the Metropolis by the existing Water Companies. 4th edition. London, by R. and J. E. Taylor, Red Lion-court, Fleet-street. 1849.

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two hours and a-half, showed $8\frac{2}{10}°$ of hardness. [There is a very remarkable fact that I have observed on the comparative result of the process of prolonged boiling, and of the process of softening by means of lime-water. Both processes result in nearly the same degree of hardness, but the lime process gives a result much less alkaline than the boiling process, although the contrary might have been expected. Thus in trials of a specimen of the Thames water, I found that boiling and that lime-water each softened the Thames to about 4°; but while the alkalinity of the boiled specimen was rather above 4°, the alkalinity of the specimen softened by lime-water was rather less than 2°; and yet in this case the lime-water had added about 13° of alkalinity to the Thames.]

30. What other results from the application of your process can you give?—The Thames I found of hardness $14\frac{4}{10}°$, of alkalinity $13\frac{6}{10}°$; this, after purification, was of hardness $4\frac{2}{10}°$, of alkalinity $1\frac{9}{10}°$; the proportion of lime-water was 3 to 38. By long keeping this same water became $13\frac{7}{10}°$ of hardness. The general result upon the waters of the Companies in London I found, by a great variety of other trials, to be this, that they acquire the same degree of softness by the process as when you mix the original water with distilled water, in the proportion of one measure of the original water to three measures of the distilled water; such is the general result as to London. I will mention another case in the neighbourhood of Watford, on the river Gade, where I found the hardness to be $18\frac{4}{10}°$, and the alkalinity $17\frac{4}{10}°$. By treating this water with one-tenth of its bulk of lime-water, the hardness was reduced to $2\frac{9}{10}°$, and the alkalinity to $1\frac{4}{10}°$; the softness of this purified water is the same as the softness of a mixture of one bulk of the original water with five bulks of pure distilled water; in other words, only one-sixth of the original hardening matter remains.

31. What would be the difference in the action of those waters, purified and unpurified, upon soap?—One hundred imperial gallons would require of the strongest white curd soap that I have ever used, the following quantities in order to form a lather:—

	Unpurified.	Purified.
East London	31 oz.	10 oz.
Thames	28 oz.	10 oz.
New River	26 oz.	9 oz.
Gade, near Watford . .	36 oz.	9 oz.
Mean . . .	$30\frac{1}{4}$	$9\frac{1}{2}$

[I reckon 400 gallons of water per head, per year, to be a moderate allowance, for so much water as is made use of along with soap, chiefly of course in the washing of clothes.] If any member of the Commission be desirous of forming an opinion for himself, how much more agreeable it would be to wash with soft water, I would recommend that he order his wash-hand basin to be supplied at night with water that has been long boiled. This water will be cool enough to be used next morning; it will have been softened by the boiling—not more

softened than by my process, probably not so much. Then by putting into one basin the water that had been boiled, and putting into another the original water unboiled, he may form some idea of the softening that the process would produce on the whole water supplied to the metropolis. Professor Clark, M.D.

32. Do you know what relation the cost of soap consumed in London bears to the gross water-rent?—I reckon the cost of soap consumed in London to be about double the gross water-rent. The quantity of soap consumed in England, Wales, and Scotland, can easily be ascertained from official returns. From these the consumpt of every individual of the population appears to be nearly 7½ lbs., or 120 ounces, which, at 1*d*. for three ounces, or 50*s*. per cwt., comes to an expense of 3*s*. 4*d*. for each person. There are no official returns from which to give the consumpt of soap in London alone; but after making diligent inquiries as to the consumpt of soap in families that washed on their own establishments, and obtaining what I believed was the best information that the trade could afford, I came to the conclusion that the average consumption of each person was about double in London what it was over all Britain—that is to say, 15 lbs., which comes to 6*s*. 8*d*. for each person. It is to be remembered that London is a hard-water district. The Commissioners must be aware that there are at present no very accurate data for an estimate of the water-rent paid by each person, in London, but 3*s*. 4*d*. seems as accurate an estimate as can now be made. Thus 10*s*. for each person is the cost of soap and water in London; 6*s*. 8*d*. for soap, and 3*s*. 4*d*. for water. Since the soap costs twice the water, whatever be the rate of saving on soap, that rate will become twice as much when reckoned on the water. For example, if the saving by softening the water be only 5 per cent. on the soap, it would be 10 per cent. on the water.

33. What is the total soap used in London?—About 1,000 tons a-month, at about 50*l*. a-ton, and along with it is used about 250 tons of carbonate of soda, at about 10*l*. a-ton, costing together 630,000*l*. a-year.

34. Does the softening of water by your process affect the taste?—It takes a little of the saline character from the taste, in consequence of the removal of the chalk. It does not appear, so far as I have had an opportunity of observing, to render the taste objectionable. The opportunities I have had of observing were these. In Aberdeen, when my friends came about my laboratory, I let them taste the purified London waters, listening to their remarks without making any; and in London I caused as many friends as visited the laboratory where I was working, to taste the purified water, and I never found one object to the taste. In Professor Graham's laboratory in University College, where a quantity of New River water had been purified and left in a large glass, the Professor told me that he observed that his laboratory pupils went to that glass for water to drink through the day, in preference to the pipe-water.

35. Would the application of your process be attended with much expense?—Two years ago I made all the inquiries I could, and my impression then was that the expense of the materials would come to somewhere about 1 per cent. upon the gross water-rent of London.

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Probably the other expenses, of interest on outlay, and of conducting the process, would not much exceed another per cent. (See Q. 54, 57—61.)

36. You are probably aware that the water supplied by the water Companies is supplied from the river Thames; is there not a marked difference between the composition of the river water and that obtained from the wells occasionally in the metropolis?—Generally speaking the wells are harder, much harder. I may give a few instances. Torrington-square well, which was the hardest I examined, stood about 80° of hardness. The well at the gate of University College stood 32°. A well in a private house, Charlotte-street, Bedford-square, stood $43\frac{1}{2}$°. Red Lion-square pump gave 61·5 of hardness. Among the London wells there is one exception, and a very notable and important one; that is, in the deep wells. I refer to the artesian wells; they are softer. I have examined the deep well of Apothecaries' Hall, the one at Combe's brewhouse, and the one at Truman and Co.'s brewhouse. They gave each almost exactly the same degree of hardness, namely, $5\frac{5}{10}$.

37. Do you happen to know the depths of those wells?—I cannot state that particularly, but they are among the deepest wells in town. There is a very remarkable peculiarity belonging to the water of those wells, which is, that they are very highly alkaline. [The degree of their alkalinity exceeds the degree of their hardness by 17°, according to an analysis recently performed at the Royal College of Chemistry, on account of the presence of a large proportion of alkaline bicarbonates.] In respect of the excess of alkalinity over the hardness, they are different from almost any other water I have examined, save that from the artesian well in Paris. The consequence of the large proportion of alkaline bicarbonates they contain is, that if you boil any of these waters you will find it become nearly as soft as water can be. Very perfectly the earthy salt is precipitated; but while you are free from earthy salts you have got so much of alkaline salts that you can very distinctly taste the alkali in the water; so that the water from any of the very deep wells in London is, in fact, when boiled, a weak solution of carbonate of soda or carbonate of potash

38. Sufficient to produce any effect?—I think small doses of alkaline salts always act medicinally on the kidneys, and I think that portion of the water is the only portion of which we can say with confidence that it does produce medicinal effect. It was on that consideration that I alluded to the alkaline bicarbonates as a most important ingredient in the water.

39. Is there any appreciable quantity of vegetable matter in the water which is in use in the metropolis?—Uniformly there is a considerable portion of vegetable matter in the water supplied to London by the companies.

40. Has the offensive smell of certain water any connexion with the presence of organic matter?—Certainly. When the water put into a glass vessel acquires an offensive smell, that can be attributed only to the presence of vegetable matter, or other organic matter undergoing a change.

41. Is the animal matter which passes into the river by the sewers

separable by filtration or any other means?—The solid portion of it may be separated by filtration; but not the portion of it held in solution. At the same time I must say that I think very undue weight has been given to the presence of organic matter, and especially of animal matter; as if, because it was inseparable by filtration, it still must retain the same offensive character as when it entered the water. I think this will appear exceedingly unlikely, when you observe what occurs in the well-known process of making nitre artificially, where such animal matter as the washings of the cow-house is converted so readily into the basis of nitric acid; when you consider how readily such matters are likewise changed in the usual process of vegetation, and when you consider, further, how readily dead animal matter changes spontaneously. For such reasons, I think that it is assuming far too much to say that such animal matter as passes into the river remains there unchanged, especially remembering how freely a river is exposed to the action of the air, and recollecting the other matters that are present, so calculated in such circumstances to increase chemical action, as, for instance, the alkaline substances present. Under such circumstances, I think it is very unlikely indeed that the elements of animal matter do not undergo change, and rapidly too, into some other state of combination.

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42. Is the presence of water insects of any consequence, and is that peculiar to London water, or have you found them in the water of other districts in England?—Those insects are not peculiar to the London waters; but the London are the first of the waters supplied for the use of the inhabitants of towns in which I ever saw them. They are not general in the waters of other towns, at least in Scotland, and are nowhere to be found except in such waters as are not in a choice state for drinking. They are an indication in general of a vegetating process going on in the water; I think I have observed, from examining a great variety of specimens of water kept in glass vessels, that the two things generally go together, the vegetating process and the breeding of those insects. Either circumstance I should apprehend to be a presumption of the other, and to indicate a state of water unfit for drinking.

43. Can you state what effect on health is likely to ensue from the constant use of water containing animal or vegetable impurities?—I am not prepared to make any statement upon that subject; nor am I aware that, in regard to a question of so much interest, there has been much accurate information obtained. However, there is one very obvious consideration as regards the health of the inhabitants, that if you have water not fit for drinking, in which there is matter offensive in any degree, by so much as the water is offensive you lessen the habit of drinking water. Now, you cannot restrict the supply of water to such quality as is naturally repulsive; you cannot thus render the inhabitants abstinent from water, without interfering with the healthful functions of their bodies. It was with no small concern that I learned how few of the inhabitants of London, and especially of the lower orders, drink water. In making my experiments upon these waters, when I inquired of the servants about me how they liked particular waters, it was with perfect surprise I discovered that they—generally mere lads—knew nothing about the taste of the water. They are the

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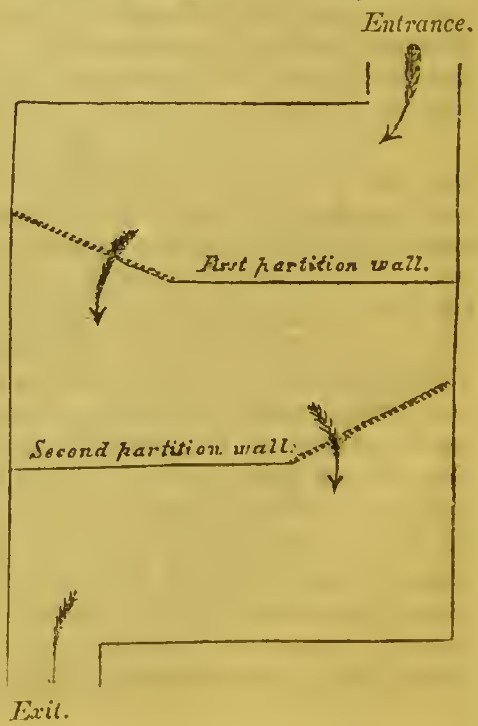
same sort of persons as would be accustomed to drink water in other places, but they have other beverages here. I should, perhaps, not speak as to the general habit of the inhabitants, but only of what little I have observed in such circumstances.

44. What do you mean by mechanical impurities?—Such impurities as you can see in water; solid matter loosely diffused through it.

45. What are the ordinary means in use for the removal of those mechanical impurities in water?—All the usual means may be reduced to two, the process of subsidence and the process of filtration.

46. Have you any suggestions to make with regard to reservoirs of subsidence?—In constructing reservoirs for water to supply a large town, there are a great many important provisions to be made. I think there is one point that must be laid down almost as a general principle, namely, that you should never unite the supplying of water to a town with the supplying of water to a canal, or to mills, or to any other mechanical object; and the reason is, that whenever you apply water to a mechanical purpose there is no end to the demand for it. Coloured or colourless, pure or impure, it will answer equally well for mechanical purposes; and the persons interested in mechanical applications of water will be quite willing to let water be taken in such as is not at all fit for drinking, for washing, or for chemical manufactories. With regard to the size of reservoirs, there are reasons why they should not be too large, and there are reasons why they should not be too small. Reservoirs should not be so large as to encourage vegetation in them. I think I have observed some reservoirs where there is this defect; they have been so large that the water remains long enough to be comparatively corrupted. This is a very grave defect; and in order in part to remedy it, the use of some substance repulsive to vegetation, in order to line the reservoir, might be expedient; for instance, asphaltum. Again, reservoirs, on the other hand, may be too small. They should always be so large as to hold a stock of water for as many days as may be necessary to avoid taking in a supply at a period when the water is not in a fit state for use, from rain or other causes. For this reason it is in general expedient that the first reservoir into which water is pumped from a river should not be far from the river, nor high above it, so that any given amount of machinery may be able to fill it the more speedily: so much with regard to the size. Then the reservoir should be used as a means of subsidence, and helps to subsidence ought to be adopted. Among other helps, I think it is expedient to have partition walls in the reservoirs. Here is a sketch I drew in the other room.—[*The Witness here produced the same.*]



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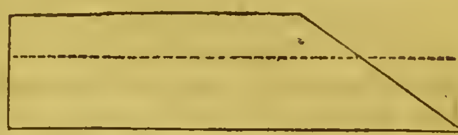
Section of the second partition wall.



Suppose the water enters at the utmost arrow, it passes round the partition walls, in the direction of the arrows, as shown in the drawing. If you observe a reservoir without partitions you will see this take place. When the wind gets up so as to sweep the reservoir, say in its length, then, the sides of the reservoir being a little above the surface of the water, the waves would not begin to be formed for some considerable distance from the wall; and, in proportion to the length, they would go on increasing in size. The partitions would have the effect of preventing the agitation in a considerable degree. These walls would have another effect; they would give a regular flow of water from the point of entrance of the water to the point of its exit; whereas without those walls it may happen, and I have observed such a thing to happen, that you may have water of one description in one part of your reservoir, and water of a different description in another part, where there is a defective flow of the water. But in a reservoir with walls, the water that has first entered the reservoir comes out first. [Such walls might also, perhaps, afford support to roofing, or other means of covering in the reservoir, and protecting the water from the action of the sun, which is a great promoter of vegetation.] Floating diagonally at the place where the water passes beyond each partition wall, there should be a floating spar, with wooden pegs in it. This is represented in the sketch of plan by dotted lines. The use of it is to stop straw, and similar floating matter, as well as to break the waves at that place. Further, with regard to the reservoir, there is a very important point that I think has not been attended to in water-works for towns, though I have observed manufacturers attend to it; that where water is to be obtained from different sources, and where, in consequence, it is of different qualities, I think it is quite necessary that, before the water comes into the reservoir, all the different kinds should be thoroughly mixed. This is the practice in the district of England where, I think, the treatment of water is best understood of any part of the United Kingdom, that is Lancashire. The practice in manufactories around Manchester almost uniformly is, where you have two different qualities of water, to mix them into one stream, and let them run together in a narrow channel pretty swiftly, and for some distance, before they come into the subsiding reservoir. One advantage arises from this: it often happens that the saline impurities of one water act upon those of another. Such an action, wherever the waters are of a kind to occasion it, is immediately produced under the arrangement described. The different waters are mixed together before they enter the reservoir, and are ready for the precipitation consequent on their mixture immediately taking place, whereas if they entered a reservoir separately, the water from one source might run into one corner, and that from the other source into another; the one might be muddy and the other clear; they might never be properly mixed; and wherever they came in contact, there would be a muddiness slowly formed. Whenever you have any dirty water, the subsidence of the dirty matter is greatly aided by mixture, and a consequent pre-

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cipitation. The mixture of different waters causes them to act on each other; occasions a readiness to precipitate, and the deposit of floating mechanical matter takes place in this manner much more readily, in consequence of the thorough admixture of the two kinds of water. The success of the filtration of water on the large scale, I think, is greater in Lancashire than in any other part of the United Kingdom. I attribute a very great portion of that success to this arrangement, for it is a point universally known to chemists, that you cannot filter water clearly unless it be in such a state that it will spontaneously deposit the solid matter by subsidence, and leave the water clear. If subsidence leaves the water still milky or unclear, the water almost universally passes through the filter milky. I would add, in regard to subsiding reservoirs, that I think water should be taken not from the bottom but from the top of the reservoir. I am sorry to observe it is almost an universal rule to take it from the bottom: the engineer finds it more easy to take it from thence.

47. By what means would you draw it off from the top?—By any known device of engineering that is expedient under the circumstances. I would take it not far from the surface. In one case of a manufactory, I recommended that there should be a large float on the top, attaching to it the open end of an exit-pipe, so that the distance from the surface of the opening for the exit of the water was always the same, the pipe having a moveable joint.

48. Will you state your opinion with regard to the different modes of filtration used on a large scale?—There are two modes of filtration that have been effectually used on the large scale, one called the Natural Filter, the other called the Lancashire Filter. I think that the natural filter was applied on a very considerable scale first, as far as I am aware, at Glasgow. On the River Clyde, a few miles above Glasgow, there is a very extensive convex, round bank of sand; buried in this bank, nearly parallel to the edge of the river, as well as to the surface of the water, and under its level, was a tunnel so constructed as to be without mortar above, but with mortar below. The water was allowed to filter into this tunnel, and to trickle from that into wells, and from thence it was pumped up for use. This method of filtration, in consequence of the success that attended the first great application of it at Glasgow, was imitated elsewhere on the banks of the same river, and in other places, but most commonly it failed. One cause which led frequently to its failure was this, that springs were found in the ground, which afforded water perhaps harder than that which was filtering. In the case of the other trials of the Clyde water, the natural filter afforded springs containing iron, and injurious for the purposes for which the water was designed, especially washing and dyeing. Such a defect must occur, more or less, wherever you have a natural spring in the ground of worse quality than the water you intend to filter. When you use the natural filter, you must advert to the liability, greater or less, of the filtration being interfered with by springs. But there is another defect, which has led me to the conclusion, that, upon the whole, natural filtration is not an expedient method for towns. The defect I refer to rests upon this consideration: the level of your filter is fixed; the level of the water in the river will

vary. In exceedingly hot weather this level is lowest; but it is in exceedingly hot weather that you require the greatest supply of water. At the time therefore when you have the greatest demand for water, you have the smallest supply; and I believe it will be found on experience, that wherever such a filter has been adopted for the supply of a town, the parties managing the water-works are compelled, about Midsummer, to take water directly from the river to supply the deficiency to the town. Now this defect is one so constant, and that so essentially belongs to the method, that I think we ought to be very cautious of adopting that as the mode of filtration in any case. I would say also, that there is probably another objection to that description of filter that you have not it under command; it may clog up by use, and if it do, you cannot clean it; at least I do not see the means of doing so. The natural filter, therefore, I do not consider eligible for use. Professor Clark, M.D.

49. Do you know the Lancashire method?—The Lancashire method may be easily described in general terms. Supposing you have a flat horizontal surface to form the bottom of the filter; that is puddled. Above this you spread gravel, and, in general, very large stones. In the spaces between those stones you have the water received and passing out by means of little tunnels near the bottom. These are formed in a variety of ways. A very good method of forming them has been recently practised, and answers very well; the using simply of agricultural draining tiles. Those little tunnels are for letting off the filtered water all around them. If you have large stones, the interstices between those large stones constitute a receptacle for holding the filtered water. Above the large stones you have large gravel, then smaller gravel, till you come to sand. The whole of the cleansing part of the filter consists of sand. This is of a larger grain than the common sea sand, except such as we see in rocky districts at the mouths of rivers on the shore; large-grained sand of a uniform size. The filter, I think, may be worked so low as four inches of the sand; I think it is constructed at about 14 inches. From 4 inches to 14 inches is a workable depth of sand. A very small depth of water above the surface of the filter is employed; in fact, in using this filter I think it is usual to see some part of the surface of the filter uncovered; the whole action is found to be concentrated at the surface. The solid matter intercepted does not penetrate perhaps so much as a quarter of an inch, so that by removing a very small film from the surface you get a clear filter; this removal is performed by a workman from time to time. I think that this process of filtration is efficacious in removing mechanical impurities to an extent that could scarcely be believed without seeing the process. What dirty water is thus filtered and used in some of the first manufactories of calico-printers, where one would think good water was at least very desirable, would not have been believed by me to be possible, if observation had not made me familiar with the fact. Clearing the filter is a matter of very small expense in a large manufactory; neither is the structure of the filter expensive. What is scraped off the top is set aside, and at the end of such a period as a year, is washed and put back again on the surface of the filter, so that no renewal of fresh sand is necessary. Such is an outline of the Lancashire filtering. There are occasionally seen in some such filters, iron

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pipes rising upright throughout the surface of the sand. These pipes are open, and communicate with the little tunnels. The use of them is simply to let the air escape, so that the pressure of the air that might be confined in the tunnels under the sand does not prevent the action of the filter. Of all the methods of filtration, I consider the Lancashire the best. It is particularly to be recommended for its cheap construction; and the facility of cleaning the filter is an important advantage.

50. Is it applicable to large bodies of water, such as are required for cities?—Yes; I have seen it applied to great paper works, which require very large supplies of water. There is no limit to the application of it.

51. Is it applicable where there is a great flow of water going into reservoirs?—I know no circumstance to hinder the application of it on any scale whatever.

52. Where there is a very rapid consumption of water; where the flow into the reservoir, and the demand for the water of the reservoir, is very rapid?—It would require in that case a larger filter. The process is so easy in its operation, and so rapid in its effect, that I am not aware that any amount of water might not be filtered by it. In Glasgow all the water is professed to be filtered for the use of a population of above 300,000. Now I have no hesitation in saying there would be less difficulty in filtering by the Lancashire process than by the methods that have been adopted there. (See Q. 64, 65.)

53. The effect of your statement is, that the different waters supplied by the London water companies, varying in hardness from 16 to 11, and so on, would be reduced by the improved process three-fourths in their hardness?—Precisely so.

54. What would be the cost of the process on any given quantity of water?—That is a calculation that cannot, from the nature of it, be made until a specific case shall arse. You can easily ascertain the quantity and the cost of the lime that is requisite, when you know the quantity and quality of water that is to be purified; and the cost of that material, according to the best information I could obtain when I made inquiry two years ago, could not be more than 10*l.* a-day, in order to purify all the water supplied to London.

55. Might it not be proper, as a means of saving expense, to purify only a part of the water, say a half, and leave the rest unpurified, for watering streets, and the like purposes?—My impression is, that the difference of expense between purifying the half and purifying the whole, consisting mainly, as it must, in the cost of the material, is so little, that it ought never to be made a question whether the whole should be purified or only a part. A halfpenny a-year would supply burnt lime to purify water for each person in the metropolis. Besides, the larger the scale, the process is the easier, and the more advantageous in its application.

56. Do you regard it as of any consequence what quality of water is used for such a purpose as watering the streets?—Not certainly as a matter of indifference. The best waters now used for watering the streets of London are probably the hard springs. They are free from vegetating matter. The pipe waters are not so; and waters with this kind of taint communicate it to other water, or other organic matter

that may come in contact with them. When it is considered how readily effluvia will rise from a heated street covered with a film of water, it ought not, I think, to be regarded as a matter of indifference whether untainted water should be used for streets. Supposing the pipe waters of London were purified by my process, they would certainly be more wholesome water for the streets; and even if to every cart of such water were added a gallon or two of lime water, a liquor very inimical to vegetation, probably it would be more wholesome still, free from any character that belongs to heated marsh water, unfavourable to vegetation, but favourable to animal matter assuming the form of nitrates. In some towns I have seen the kennels dammed up, and the water sprinkled thence by a shovel, or some such instrument. Thus, no doubt, the dust is laid; but the effluvia is a more unwholesome evil than the dust. Water tainted and smelling, as I have occasionally observed water in London, is worse for watering streets than even kennel water. Professor Clark, M.D.

57. For the whole supply of London, the expense of the burnt lime would be 3,650*l.* a-year, according to your calculation. What other expenses would be incident to carrying it into effect?—The other expenses would depend entirely upon what conveniences the water companies have just now. The West Middlesex Company, for instance, have extensive reservoirs, not more extensive than under suitable arrangements would be necessary for the proper treatment of the water. There the expense might be very little, for they are in possession of reservoirs. If the purifying process was to be applied by a company that possesses no reservoirs, or inadequate reservoirs, then there would come in the expense of the additional reservoirs; but, independent of the providing of the reservoirs to such an extent as is at present necessary for effecting subsidence properly, the expense of the process and of the erections for working it, would be very small.

58. What would be the additional expense to that company which had a reservoir?—That is a question I am not prepared to answer, from the circumstance that having invited the attention of the various water companies to this process, I found that with one exception, and hardly a second, they civilly declined so much as to look at the process. The principal exception occurred in the case of the Grand Junction Water Company, of which both the secretary and the engineer inspected the operation of the process on a small scale, and also satisfied themselves of the remarkable changes of quality induced by the process: at first the secretary, and after a long interval, one or two directors of the West Middlesex did also satisfy themselves upon the same points, but it was merely looking at the process, nothing more.

59. Though not prepared to make the calculation, can you give any approximation to the other expenses?—I cannot profess to offer any advised approximation, for the point is one on which an engineer must be the judge. I was prepared to point out to the engineer of any of the water companies all that was necessary to be attended to for doing justice to the process, expecting he would state to his own company what the expense would be in the instance of that particular company; and, if for my own satisfaction, I were to make an estimate applicable to the case of any water company in London, it could only be by

Professor Clark, M.D. employing an engineer. That, however, would be so speculative a procedure, that I have not thought it called for on my part. I was indeed very anxious to furnish the engineers of the water companies with every information in my power, so as to enable each company to form an estimate of the expense by its own engineer, and not from any opinion of mine, nor of any engineer employed by me; but the engineer of only one of the companies availed himself of the invitation to witness the process; and whether he ever formed an estimate for the information of the company, I never heard. [As far as I have since been able to gather from intercourse with engineers, it is likely that the apparatus necessary for working out my process on the large scale, will be pretty much the same in expense as apparatus for working out the process of filtration on a like scale. After the application of my process no filtration is necessary.]

60. You have been asked with regard to the expense; have you any hesitation yourself in stating, though you do not give a precise answer as to the amount, that your processes are not in themselves essentially expensive?—Certainly, such is my impression.

61. They will consist essentially in effecting the solution of lime in the first instance; secondly, in the proper commixture of that solution with the water to be purified; and thirdly, in affording facility of deposition?—Precisely so. Indeed, I find it impossible to think of my process as involving the consumers in additional expense; for, supposing my anticipations to be so far erroneous that, instead of costing 1*d.* per head of population, the purification, and consequent softening of the water, should cost so much as 4*d.* a head, still this 4*d.* of outlay on the water-rent would be compensated to the consumer by a saving of only three-quarters of a pound, that is, one-twentieth of the soap required for the consumption of each person; and the saving, arising from the softness of water, in the wear and tear of linen, in the quantity required of such an article as tea, and in the wear and tear of boilers of all kinds, has to be added to the saving in soap.

62. When you refer to the condition of the water in London, and particularly to that quality of hardness, are you to be understood that your process consists in applying the amount of lime which is necessary for the deposition of the super-carbonate, and not beyond that?—No more, and no less; but especially no more.

63. When you refer to the quality of water, and speak of the hardness of water in different districts of the country, have you also noticed the amount of organic matter in water from wells in London, or do you wish that those observations should be considered as applying principally, if not entirely, to the water supplied by the companies?—My observations were mainly directed to the waters supplied by the companies, because they were the waters I was best acquainted with. With regard to well waters in London, except a few here and there, I have been very little acquainted with them. Anybody may observe that water when kept in a bed-room, or a sitting-room, if it be the New River water, or the Thames water, has a tendency, if kept a few days, to vegetate, and cover the bottom of the water-bottles with vegetation. Now, I have not observed in the particular spring waters that I have been accustomed to drink in London any such tendency. Whether

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this freedom from vegetation is universal in the spring water of London, I am not prepared to say.

64. In referring to the filtration of water, you mentioned that it is only the mechanical impurities that are removed by filtration ?—I did so.

65. Do you mean that to apply to a filter of sand or to filters generally ?—To artificial filters, such as are generally used. I would like to make a statement in reference to the habits of water in regard to a point that I think is not generally known, but that came once under my observation very strongly. I believe that filtration, through a great depth of filtering material, such as occurs in the operations of nature, does take away colour. I believe that, from what I have observed, particularly in the case of water filtering from a pond on the top of a small hill so as to escape as a large spring near the bottom; but what the nature of the discolouring process is it might not be easy to state, and perhaps not easy to conjecture. But the quality alluded to as belonging to water must be kept in view in attempting to explain this discolouration, and to explain changes that take place in the water of rivers and lakes, else there will be unfounded prejudices entertained; it is the tendency water has to purify itself spontaneously by natural processes. We never do see a very large body of water collected together, except in a pretty clear state; there is a natural process, a vegetating one, that goes on very readily, freeing the water from vegetable matter and all that sort of matter that makes water what we call dirty. If you look to a stream coming from a dye-work, you may discover in it, at a very little distance from the dye-work, a vegetation that takes place; if it be, for instance, from a madder-work, you will find a reddish vegetation. The vegetation I refer to is very easily distinguished by its assuming a form that reminds you of a sooty brush. When you lift it out of the water it is slimy. You can see it in its natural form only in the water. Even in the common kennels in the streets, if they be kept constantly running, and be not frequently supplied with fresh water, you will find such vegetable matter; this results from a spontaneous vegetation. In its progress, a purification of the water takes place universally. A remarkable occurrence took place in an action at law, where it was alleged that a certain water was destroyed for certain purposes by a dye-work. Specimens had been taken for more than a year. Those were bottled up, and sealed and labelled, and the individuals that collected the specimens were prepared to swear those were collected fairly, and in the state in which they were preserved. I had an opportunity of examining all those specimens, and although they were marked "brown water," "red water," and so forth, I found all of those waters had spontaneously cleared. The impure colouring matter had subsided, not as small dust, but in flakes that could be shaken up, and that floated in clots. Such is the process which I apprehend may account for how very readily impure water left for some time comes to be spontaneously purified. Probably it is such a process as that which occurs in a natural filter, where the water passes a certain distance; and probably it is that which takes away the colouring matter; but that I do not know. I might perhaps also mention, that any process which throws

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solid matter down from solution, sends down also diffused dirty matter; for instance, any gentleman in London, who has boiled water brought to him to shave with, may occasionally see a powder settled at the bottom: this is chalk; but it is not white, for all the colouring has gone down with it. So likewise, in my process of precipitating chalk by lime-water, what falls is not white; it is coloured differently from pure chalk. The purified water, too, is less coloured than the original water, because the colouring matter has fallen down with the chalk.

66. Though it may have been previously in solution?—Yes.

67. In reference to the process by which you purify water, it essentially depends upon the deposition of the carbonate of lime. Have you had any opportunity of forming an opinion as to the time that may be required for such deposition in works on a large scale, and also in respect of the probable influence of such deposition upon the materials used for filtration, and whether you can effect that deposition so as to be secured against any tendency to increase the crust that might appear in the pipes in some cases?—With regard to the time necessary, I have employed, as the best means of observation, large glass vessels, because there I could best see what takes place. Ultimately I came to use vessels of the size of seven gallons. It was in such vessels I practised the process here, when I invited the inspection of the water companies. When this process is applied, there is this peculiarity, that the more the process has to do, the quicker it does it, and the more decisively. For instance, a water of 16° of hardness will deposit faster than one of 12°; a water of 12° of hardness will deposit faster than one of 8°; and water of 12°, according to my observation, may be reasonably expected to clear in 24 hours. Indeed, my impression is, that such water generally clears in 16 hours after mixture with lime-water. With regard to a water of 10°, I should expect, though I have no experience, that the deposition would be still less rapid. As you get below the hardness of 8°, I should expect the process would be so slow that it would become a question whether the application of the process was expedient; and the only rule I was able to give in the specification was, that every particular water should be treated, in a suitable proportion, with lime-water, and the time of its precipitation observed, so as to afford an opportunity of witnessing the habit of the water when under the operation of this process, before coming to the resolution of adopting it. The precipitation of the chalk formed, along with the mechanical impurities, is so very effectual under this process, that no filtration would be needed. With regard to the pipes, if a reasonable time were permitted for deposition in reservoirs, certainly I should not be prepared to expect any incrustation in the pipes. With regard to incrustation, I may also state, that the water which has undergone this process affords no visible deposit on boiling, although the unpurified water does so extensively.

68. Are you aware whether the insects you refer to are destroyed by lime in the quantity employed in your process?—Undoubtedly lime does destroy the insects; so much was it my impression that they were all destroyed, that I stated so broadly in my pamphlet; but I afterwards occasionally observed one or two to escape in some experi-

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ments, and I suppose, also, that some of the insects are of a more hardy kind than others, and so escape. My impression for a long time was that every one of these creatures was destroyed.

69. Have you ever, in examining the matter precipitated during the process, found reason to believe, from actual experiment, that there is organic matter thrown down along with the material so deposited ?—The evidence for believing that the process removes colouring vegetable matter consists in the appearance that we get. For instance, if the water be brownish, we get the chalk brownish; whereas, if we use the very same lime-water, and precipitate chalk from it by any fitting agent dissolved in distilled water, we get it pure white; besides this, the water floating above the coloured chalk precipitated in purifying a London water is freer from a portion of colouring and organic matter than the original water compared with it side by side, for such matter has gone to the bottom in the chalk. But I have also dissolved the precipitate formed in the purifying process by means of very dilute muriatic acid, and have in this manner seen left the remains of insects that had been killed by the process and buried in the precipitate.

70. What qualities injurious to any special use are imparted to water by the different geological characters of the countries from whence it arises, or over which it flows ?—The connexion between the qualities of a water and the character of its geological source, is a question of very great interest, and which I much hope may be answered very soon. I believe that it will be found, that out of every specific kind of rock will come either exactly the same quality of spring-water, or within a very small range the same; so that you will be able to predicate from the rock what kind of water you will get; and I think it will be possible very soon to predicate from the water what kind of rock it comes from, and in a given district, to know the part of the country from which any specimen of water may have been taken. Last winter I was on the eve of commencing a series of experiments on that very point, selecting for examination only spring-waters coming directly from known rocks, when illness interfered and put a stop to my researches. The question is, however, of the highest importance practically. The facilities for making researches on the qualities of waters, so far as connected with the geological character of the district, are great, by means of the new processes I alluded to for examining water. By those processes, an ordinary water may now be examined with great accuracy and great facility. You can, in the course of a day, examine as many waters as would have taken weeks before. Although not at present prepared to answer this question particularly, I am entitled to say in general that there is a very close connexion between the qualities of water and the geological character of its locality; and ever since it has become possible to examine the useful qualities of water so easily, I have had an anxious desire to see the examination of waters embraced as part of the operations of the national geological survey.

71. Will you state the different effect produced on water by the conveyance of it through lead or through iron pipes ?—Through iron pipes, I think, there is no apprehension of risk to be entertained, except simply from the corrosion of the pipes, and the ill colour that would be

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imparted to linen washed with it. With respect to lead pipes, I would say that the less lead is used the better in all cases; because, independent of carbonic acid, lead is very susceptible of being oxidized on the surface, and carried off rapidly, so that the powder of oxidated lead is apt to be conveyed into pipes along with the water. In general, the less lead is used the better; but it may be used for conveying water from the main iron pipes in the streets to the houses, provided the water be on the system of constant supply. The precaution, however, will be necessary to let the water run for five or ten minutes if the pipes have been for any considerable time out of use.

72. What is likely to be the effect of the oxidation of metal pipes on the health of the population where the mode of supply is one by which the pipes are alternately full and empty?—There is risk of a greater action on the pipes when they are alternately full and empty, than when constantly full, in consequence of the greater exposure to the action of air, which is essential almost to chemical action on the pipes. Perhaps I may be allowed to add, with reference to the action of water upon lead, that I tried very carefully, in University College here, the action of the New River water in its natural state, and of the same when purified by my process, against distilled water; and I found that while the distilled water acted very readily, that purified by my process did not act perceptibly; neither did the unpurified water. (See Q. 18.)

73. Have you at any time found the organic impurities of London water in so large a quantity as to be evident to the senses of smell or taste?—I have; one instance occurs in the note-book before me, "10 September, 1841; West Middlesex water, obtained from Percy-street, Tottenham Court-road, smelled like bilge-water;" I remember inquiring, and I believe that the offensive smell is apt to be much aggravated by the state of the intermediate cisterns that are attached to the houses.

74. In those cases where it is not so evident, you were understood to say that you considered the presence of animalcules as a sign of the water likewise containing small quantities of animal or vegetable matter in a state of change?—I cannot speak at all as a naturalist; I might speak perhaps erroneously; but I meant merely to make this observation: I have seen the two so constantly accompanying each other, the water insects and vegetating matter, that I have accounted them companion circumstances.

75. Are the animalcules of which you speak those visible to the naked eye, or those which you discovered by a microscope?—I speak only of such as I have observed by the naked eye; but it is wonderful how the naked eye improves in its power of observation by some practice in watching those animalcules. In a globular glass vessel of crystal, or in a basin of pure white, they are very easily discerned.

76. Have you found any water supplied to the metropolis more especially characterised by those animalcules than other?—I found the animalcules to abound in the waters of all the companies. I have lately examined a specimen of water from a cistern in the house of a friend in London, who was of opinion that the water was of late somewhat harder than usual, and it was only to try the hardness that I obtained the specimen The hardness proved to be 14°, which is

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harder than the pipe water commonly is. But before trying the hardness, I had the curiosity to count as many monoculi as I could distinguish in sun light by the naked eye. For this purpose I divided the specimen, which consisted of a quarter of a pint, into three parts. The monoculi are easily distinguishable by their darting motions. I found in the quarter of a pint 14 or 15, I was not sure which. This comes to between 56 and 60 a pint, and 450 and 480 a gallon. But the real number of creatures visible to the naked eye was of course more than this. As to the smaller creatures, visible only by the microscope, I made no observations. The servant had no instruction in taking the specimen, but only to rinse the bottle well with the water before filling the bottle, and that he was to take the water from the pipe, and not the filtered water that was used in the house. The specimen did not strike an eye accustomed to the London waters as at all unusual.

77. Do you account this common?—I have never found them in the Scotch waters that I had been accustomed to in towns, nor indeed had I ever observed them at all in any town's water, till I examined London water.

78. Do you think the poor inhabitants of London are prevented from drinking the water supplied to them from finding objectionable matter in it?—Certainly.

79. Your experience being, that these classes of impurities are, if not quite exclusively, very peculiarly characteristic of the water supplied to London, should you not be of opinion that they might be accounted for by the quantity of decaying animal and vegetable substances carried into the Thames by the sewers?—Not so; for I find these creatures to abound in the New River and in the waters of the West Middlesex and Grand Junction Companies, although these are taken from the river much above any part affected by the sewage of London.

80. Whatever would diminish the quantity of decaying organic matter carried into the water, would be likely to diminish the quantity of these animalcules which are to be found?—Certainly; and such a diminution, it appeared to me, would be one of the effects produced by my process.

81. Are you to be understood that you have been in communication with some of the water companies in London respecting the introduction of your plan?—With all the water companies without exception.

82. Did you submit to them any specific arrangement by which it was to be carried out?—No; that was not the nature of my communication. I sent a circular to them, enclosing some copies of my pamphlet, explanatory of the process, stating to each company that I should be exceedingly happy to afford to gentlemen connected with it an opportunity of witnessing the new process, and of each satisfying himself as to the changes thereby produced in the water supplied by the company, and mentioning that I would so arrange that an hour might suffice to enable any gentleman to appreciate the improvements in the water resulting from the invention. No notice whatever was taken of my communication by two companies; another was too much engaged with other operations to take my process into consideration; but they said they felt great interest in it, and they were so good as to recommend me to try whether brewers, dyers, and other large consumers in

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their district would give it a trial. A fourth company thanked me for my "polite attention," and promised to read my pamphlet. I waited a month in expectation of learning the result of the promised perusal, but not hearing from them, I again wrote to the secretary, and received from him the following answer:—"At a meeting of our Board of Directors to-day I read your letter, dated 5th instant, to the gentlemen present." This was the whole of their answer. I heard from them no more. Then there was another company who promptly informed me, that having reached perfection, the sending my pamphlet to them was quite needless. As to the West Middlesex Company the secretary was very polite to me, and immediately came to look at my experiments, and expressed himself quite satisfied with the accuracy of the statements in my pamphlet. The directors for a long time declined to be witnesses of my operations, because they conceived that their water had been "bright, pure, and salubrious" for two years. After some weeks, however, one or two of the directors did venture to look at my operations, but thereafter I heard from them no more. The Grand Junction Water Company, by their secretary and engineer, inspected the process with a consideration that was very gratifying to me; but neither from them have I heard anything for near two years. The New River Company, without having sent anybody to see the process, gave an opinion that the process could not be worked on a large scale, or would be much more easily and economically applied by consumers on the small scale, more especially as the proposed purification would not be required, except for a very small portion of the water.

83. Have you not heard from some engineers of a water-work that there would be some mechanical difficulty in carrying out your plan on a large scale?—I have heard no such objection from any engineer of a water-work. Among such engineers connected with London, I have had business intercourse only with one gentleman, the engineer of the Grand Junction Water Company. He examined the process on the small scale, and conversed with me on the subject, with all the intelligence that might be expected from a well-informed man in his profession, but I do not remember any such difficulty being suggested by him. With one other engineer, that of the Chelsea Company, I had an accidental meeting in the country last summer, and had an opportunity of conversing with him on the subject; and I remember one remark he made was, that when orders were given by the directors for the application of such a process, he had no doubt that the means would be found.

84. Was there no objection made to the quality of the purified water?—One objection was made, on the suggestion, I understood, of a medical author of some name. It was that the depriving the water we drink of its chalk, might prove injurious to the bones of the inhabitants. The idea was founded on this consideration, there is lime in chalk and there is lime in bones: if you deprive the water we drink of one thing that contains lime, you must also deprive our bones of another thing that contains lime.

85. Had you no reply to offer to that objection?—Although much concerned to discover that the state of medical science in London could permit such a suggestion being made, and although much amused at the earnest conviction with which the objection was repeated, yet I cer-

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tainly did not think a scientific answer called for; but I did suggest that the purifying process might still leave as much lime as was required for the bones, since in the town of my residence, there had been long water in general use containing much less lime than the purified water would contain, and yet the inhabitants were among the largest boned of the Queen's subjects.

86. Has any plan occurred to you on a large scale for the purpose of mixing lime-water in an extensive reservoir?—Certainly.

87. Will you explain it?—The method I think the most obvious would be, first, to determine, by the rules given in my specification, the proportion of lime-water necessary. Suppose the proportion to be 1 of lime-water to 14 of unpurified water. I take for granted there are a great variety of means, and of known rules, whereby an engineer can apportion and mix lime-water and unpurified water in the proportion of 1 measure to 14 measures. It would be presumption for me to suggest to any engineer the best method to select; but one obvious expedient that would occur to me would be, supposing by any process you could have one pipe issuing with lime-water and one or more pipes issuing with water to be purified 14 times as much, so as to mix the waters together; let the mixture run to and fro in a swift stream in a narrow channel in the usual method of mixing water in Lancashire; let the stream at last come into a reservoir. After such a plan as this, water should be introduced, after mixture, into reservoirs, and therein left to clear by subsidence; and my idea of the proper working of the purifying process on a large scale would be, that there should be a constant issuing in of the mixture at the one end of a large reservoir, and a constant flowing out of the clear purified water at the other.

88. You are aware that there have been Committees of the House of Commons on the subject of the supply of water to the metropolis?—I have read all the Reports.

89. You have seen, then, the mode in which it was proposed by the late Mr. Telford to furnish an increased supply of water?—Yes.

90. He proposed to take it from Hertfordshire on one side, and Surrey on the other; what opinion have you formed as to the modes suggested?—My real impression, from a consideration of the whole subject of water in connexion with London, is that the source of supply that should not be departed from is the Thames, it is so very copious. Then, with regard to the supply of water to London from a distance, there are many points that one would like to know beforehand; for instance, I found some water in the neighbourhood of Watford, in one of the rivers, the Gade, about one-half harder than the water here. One would require to know a little more about the hardness of all the waters that have been proposed to be brought to London, and to know whether there would not be a tendency to vegetation in conveying it from the source to London, at least if the water is to be conveyed in open channels. I do not mean absolutely to say there would be as much vegetation as we now have in the London waters; but I should like to see, from the experience of other places, whether such would not be the result. My opinion is, that there would be as much vegetation and as many insects as from those waters.

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91. On the whole, from your consideration of the subject, you think the Thames would probably be the source from which to derive the additional supply to the metropolis?—For this reason, as well as others, that where there is such a river there is an inexhaustible supply; and there are so many instances where, having started with a limited supply, the inhabitants have experienced considerable inconvenience from a deficiency, that I do not think it would be desirable to look for a supply from any source but a large river. I have recently examined a specimen of spring-water from the neighbourhood of Watford, with which it has been proposed to supply a part of the metropolis. I found this water about 17° of hardness. By the lime process it was reduced to 3°. It seems a very wholesome and pleasant-tasted water, and is remarkably free from organic matter. I found it to contain a trace of nitrates, which I hold to be a very strong presumption, that whatever portion of organic matter it may have originally held, that matter has undergone a complete change. I could not find in it any trace of ammonia, which occurs very frequently, or at least may easily be produced, in the organic matter of drainage water. Of course I can give no opinion whatever as to the quantity of such water that may be obtained, nor of the engineering advantages or disadvantages that might be peculiar to this source of supply; but I think very favourably of the quality, which may be compared to the springs that supply the Thames.

92. You contemplate the alteration of the Thames water by the process you refer to, not by taking it at a higher source?—Applying the process, you get the Thames and the New River, and probably most other rivers within reach of London, so slightly different when they are purified, that it is as well to take what you have in abundance and at hand.

93. If that be the case, and by the application of the process you speak of they are brought to the same degree of improvement, would it not be best to take that water which can be procured the cheapest?—Certainly.

94. Are you to be understood that, notwithstanding your process, a considerable quantity of animal and vegetable matter would still remain in solution?—Not a considerable quantity; the greatest part goes down, and goes down manifestly too, immediately.

95. To that portion which would remain, you would not attach much importance in reference to the public health?—Not much. Still, if it were possible to remove what little remains by any easy and cheap process I knew of, I would propose its removal.

96. Have you any farther suggestion to offer relating to water?—There is one point I will take the liberty of suggesting to the Commissioners, and it is this, I think it would be of prodigious public service if an examination were made by some gentleman in the Commission of the pipe waters, and the favourite wells in use in the principal towns in England. It is now so very easy to come into communication with persons having projects for bringing water into towns, that I am aware from experience, how important it is to possess a general knowledge of the qualities of water such as is usually elsewhere supplied, as well as the qualities of the water that is the subject of the project, and of

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other accessible waters in the immediate vicinity. Formerly, that would have occasioned an enormous expense; but now, the hardness can be taken in less than an hour; the alkalinity would not take more than two hours in any case, and I am quite sure that a general examination of the principal waters in use in the towns of England would be of great value to the public. I am quite sure it would be an important undertaking on behalf of the public. As a motive for the undertaking, I may mention the degree of accuracy that can be attained in the process of ascertaining the total earthy matter present in any water in so short a time. I have frequently taken the hardness of London waters at the University College. Supposing the hardness of the water were 14°, we operate in this process not on a whole gallon, but only on the 70th part of a gallon, containing $\frac{14}{70}$ths, or $\frac{1}{5}$th of a grain. In repeating this experiment, we can come to within $\frac{1}{10}$th; that is to say, if the experiment be performed with ordinary care, the highest result will not be more than $14\frac{1}{10}$ths, nor the lowest lower than $13\frac{9}{10}$ths. Thus, you may repeat the experiment so as to ascertain within the 140th part of the $\frac{1}{5}$th of a grain; that is, the 700th part of a grain. In regard to comparative results in quantity, there is this other reason: a great many analyses were formerly made of the Thames water and other waters in the neighbourhood of London. Some of the Commissioners will be able to appreciate this consideration. Different methods have been employed by different chemists. I am quite sure that any competent scientific chemist, taking all the analyses together, will find that the results are valuable only in such analyses, or chiefly in such analyses, as have been performed by the same chemist. You cannot compare the result of the analysis by A. B. of one water, with the result of the analysis by C. D. of another water; although you may safely compare with each other the analyses of two waters by A. B., or of two by C. D. But the new processes for the testing of waters start from solutions so easy to be made, and the operations are so easy and simple, that you may look with confidence to uniform results, by whosesoever hands performed. The results will thus always afford an easy and accurate means of comparing different waters with each other or of comparing the same water with itself at different seasons.

[*The Witness gave in the following note in writing as an addition to his Evidence.*]

Living in a town with a population of nearly 70,000 inhabitants, where the water is supplied, not by a joint stock company, but by the Commissioners of Police, who are elected by the rate-payers, it has often occurred to me to question the policy of allowing water to be supplied to a town by a joint-stock company in any case whatsoever. The extensive pipes laid throughout all the streets, and branching to most of the houses, cannot conveniently, nor without a great sacrifice of expense, be laid in a second set, much less in a third; therefore competition, such as occurs in the supply of bread and meat, or of like articles of demand, is out of the question in regard to the supply of water on a large scale. The establishing of a joint-stock company for the supply of a town with water, is the establishing a monopoly of

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trading persons, having the power, without responsibility, of taxing the inhabitants for their own benefit. The practical check on any crying excess in their charge, and on their heedlessness about supplying water of a proper quality, lies mainly in the apprehension of a second company being established; but since no new works can be established without an Act of Parliament, and without risk of competition with the old company, such as almost always proves ruinous to both; and since, in order to establish the new company, an agitation in the community has to take place, the check is not of a desirable kind; neither is it effectual in the generality of cases. There is no town that I know supplied with so good water as Aberdeen, or having the supply managed in a more satisfactory manner. The gas-works there are the property of a joint-stock company, and although there is as little reason to complain of that company as there can be of any joint-stock company situated in like circumstances, still there is a strong feeling of regret among my townsmen, that the free revenue derived from the gas should go to the pockets of trading monopolists rather than to the revenue of the town, and that the gas is not, like the water, under the direction of the Police Commissioners.

T. C.

John Thomas Cooper, Esq., examined.

Mr. Cooper.

1. With your practice you have examined a great number of different waters?—I have during the last 25 or 30 years been actively engaged in the examination and analysis of water of various kinds and qualities; that is to say, of what are termed mineral waters, such as are used for medical purposes, of ordinary spring, river, and pond waters, as regards their fitness for employment and use by manufacturers; and very frequently, indeed, by individuals residing in the country, about to supply their mansions or dwellings with water for domestic purposes. In the latter case I have frequently had three, four, or more specimens sent me, to report upon and to recommend that which, in my opinion, has appeared to me the best, under all the circumstances of the case, to be adopted for use.

2. You have analyzed the water of the Thames?—I have repeatedly analyzed the water of the Thames, taken at several places and at various seasons, the highest point being at Windsor; the lowest, the entrance to the Surrey Canal.

3. What is the general character of your analysis?—The results of my examinations and analysis, as regards the contamination (if it may be so termed) of the Thames water with mineral matter, from whatever point it was taken, does not materially differ; that is to say, about 20 grains (sometimes a grain or two more or less) of solid mineral matter I have obtained from a gallon of it by careful evaporation to dryness; and it seems to me, from long experience in the use of this water, that the sulphate of lime which it invariably contains, is the mineral ingredient that varies the most in quantity; being in some cases as low as about one grain, in others as high as nearly three grains in a gallon.

It is to this impregnation, and to the carbonate of lime, which is always present in it, to the amount of about 16 or 17 grains in a gallon, that the hardness, as it is termed, is to be attributed: that these calcareous matters are variable, every one who has used the Thames water for ablution must have had ample experience. Three substances constitute the principle of the mineral impregnations; there is, however, beside these a small quantity of common salt; a still smaller amount of a magnesian salt; some silica, and occasionally oxid iron in very minute quantities, with variable quantities of organic matter. Mr. Cooper.

4. Is not the quality of the water a good deal affected by the nature of the atmosphere to which it is exposed?

5. Have you any doubt that water exposed to an impure atmosphere is capable of absorbing its impurities and this becoming noxious.

Ans. 4 and 5. I can have no doubt whatever that from the known tendency of water to imbibe odours and taints of any kind from exposure to their influence, but that water subjected to the impure atmosphere of any crowded situation, rendered more impure from deficient ventilation, that it will become in proportion to the surface exposed, and the length of time of exposure, sufficiently imbued with matter, not cognizable to the chemist, but palpably recognizable to the senses, as to be unpalatable, and, no doubt, unwholesome.

6. Can you give any instances in which this has happened, and any illustrations of the effects upon the living system and upon the health? —I do not at this time recollect any instance of the kind to which you allude.

7. Besides the chemical analysis of water, have you attended to the amount of organic matter contained in it in different instances?—The amount in weight of organic matter contained at any time in any natural water is always very small, but, in my estimation, is not on that account to be disregarded; it is notorious that filtered Thames water when taken on board ship in a short time becomes putrid and unfit for use; this is only to be attributed to the presence of organic matter originally existing in the water reacting on the sulphate of lime, or any other sulphate it may contain, thereby engendering the production of sulphuretted hydrogen; then, as soon as the whole of the organic matter has become decomposed, the sulphuretted hydrogen partly escapes into the atmosphere by the exposure of the water to its influence, and any that may remain in the water becomes in the course of time, by the absorption of atmospheric oxygen, sufficiently oxidized as not to be distinguished. While on this subject I may relate a circumstance that occurred about two years since in my own laboratory. I have a still that is used for no other purpose than distilling water; the accumulated bottoms of a number of distillations were accidentally suffered to boil to dryness, and became subsequently heated to that extent that decomposition of them was effected; the stench produced by the decomposition of the organic matter was peculiar, and not to be mistaken as that resulting from animal produce, and so persistent was it as to infect the produce of many subsequent distillations, although every care was taken to cleanse the still and its appurtenances almost immediately after the occurrence.

8. With reference to the influence of water on health, do you not think that an inquiry into the quantity of organic matter contained in

Mr. Cooper. it, is as necessary as an inquiry into its chemical properties?—I am decidedly of opinion that an inquiry into the amount of organic matter in any water intended for domestic employment is of equal, if not of greater importance, than the deterioration of what is usually termed the saline or chemical constituents, which latter, as I have already stated, does not generally exceed 20 grains in a gallon of the water of the Thames, and these ingredients being comparatively if not wholly inert in their action on the human system, when taken internally, even suppose the whole gallon to be imbibed in the course of the day; it is nevertheless true, that in an economical point of view as regards the saving of soap, or extracting a better infusion from malt, as in brewing, or for the purposes of the tea-table, in obtaining a better infusion in the tea-pot from an equal quantity of tea, a water containing the smallest amount of calcareous salts is to be preferred; but these matters I hold to be of comparatively little importance when we have under consideration the question as to what kind of water ought a city or town to be supplied with, to give to the inhabitants of all grades in society all the advantages as regards health and economy in its employment? If this question were to be put directly to me, I should answer, The water obtained from the chalk stratum underneath us in London appears to me to possess every requisite for domestic employment; that is to say, it is comparatively free from calcareous salts, also from any organic matter liable to suffer decomposition or become putrid, and it is exceedingly soft from its containing a notable quantity of carbonate of soda, thereby it possesses the property of economising soap in washing, and would enable us to obtain in all cases a better extract from any material exposed to its action, either when used hot or cold. I am free to confess that I take the Artesian well water, such as that of Trafalgar-square (which I have very carefully analyzed), and that also of Her Majesty's Mint, as the beau ideal of what a water ought to be for the supply of a city or town, but as there are places in great number out of the reach of such a supply, I can only then say, take the water of Trafalgar-square as the standard of comparison, and select that which approximates to it the nearest in all its qualities.

9. What are the chief conditions which influence the greater or less contamination of water with organic matter?—The drainage of London and the tidal influence.

10. What is your opinion as to the value of Thames water as a supply for the metropolis; say, at Battersea, at Chelsea, and at London Bridge?—I am of opinion that neither of the places to which allusion has been made are proper places from which water ought to be taken, inasmuch as they are all within the influence of the tide: consequently the influx of organic matter from the drainage of the town, which is constant, is, in fact, never got rid of, but I am of opinion is continually on the increase.

11. What is your opinion as to the value of Artesian wells as a source of supply with reference particularly to the quantity and quality of the water thus to be obtained?—I consider I have already replied to one of the questions propounded, that as respects the quality of the Artesian-well water; and as to the quantity capable of being afforded by wells, it, of course, must as yet be a matter of speculation; but I

gave that matter, in conjunction with some others, a good deal of consideration about 14 years since, and I came then to the conclusion that an abundant supply was obtainable, since which period I have had no reason to alter the opinion I then formed, but, on the contrary, all that I have since learned has confirmed it. Mr. Cooper.

12. You were called upon to examine the water of the Surrey Canal. Will you state the result of your examination?—It is, to the best of my recollection, 15 or 20 years since I was called upon by a Water Company on the south side of the river to examine the water of the Surrey Canal. This I did by taking specimens at several points between its entrance at Rotherhithe and its termination at Camberwell. The results of that examination showed an increase of specific gravity, a corresponding increase of saline matters, and also of organic matters, from its entrance to its termination, attributable, no doubt, on the one hand to evaporation by atmospheric influence, and on the other to its stagnation or comparatively small change it undergoes by the traverse of barges.

13. Have you attended to the question of the constant as compared with the intermittent mode of supply?

14. Do you conceive there would be any difficulty in applying the system of constant supply to the metropolis?

15. What do you conceive to be the peculiar advantages of the constant mode of supply?—One of the advantages of a constant supply, I conceive, will be more in favour of the poorer class of consumers than the richer; for as the poor have but little convenience for storing up the quantity of water they may require for their use from day to day, and if they had, there is a probability of its becoming more or less contaminated by being kept in their too much crowded dwellings; while those who are better to do in the world are well provided with well constructed receptacles, where it may be (if sufficient precautions are taken) retained for a time without undergoing any material change.

16. What in your opinion are the disadvantages?—I am not aware of any disadvantage.

17. Have you observed any instances of the contamination of water by its retention in tanks, cisterns, and butts?—I know of many instances: some in my own premises, and others in those of my friends, where the Thames water with which they are supplied has, in my cisterns and in theirs, become unfit for use, and the supply-pipes occasionally been stopped up, by decaying or decayed confervæ.

18. Do you think that contaminations may take place to such an extent as to prove injurious to health?—If the imbibition into the human system of decaying vegetable or animal matter be injurious to health, which I believe is agreed on all hands to be the case, it must follow as a consequence that, if water becomes in any degree contaminated by putrescent matter from any cause whatever, that in proportion as the amount of decaying matter of either kind may be increased, so will the insalubrity of the water be increased also.

19. What is your opinion of the practice of exposing water in these receptacles for domestic purposes, in the close and dirty yards and courts in the poorer districts of the metropolis?

20. Have you known any instances of injurious effects from this cause during the prevalence of epidemics or otherwise?

Mr. Cooper.

21. What is your observation of the Company's water which you receive at your own residence?—It frequently comes in tainted with the smell of decaying animal or vegetable matter; it having, in fact, a slightly putrescent smell and taste.

22. Is it delivered filtered, or free from matter in suspension?—It comes in much clearer than it used to do, and deposits very little matter in the bottoms of the vessels in which it is detained. I think it more likely that it is cleared by subsidence, than by filtration.

23. Do you filter the water you use?—Yes, we filter all the water we use for culinary purposes.

24. Are we to understand then that the smell you speak of is perceptible even after filtration?—Yes.

25. It is, perhaps, superfluous to ask you, as a chemist, whether you consider that this is a water which ought to be supplied to a population?—I certainly think not.

26. What description of filter do you use?—One made of finely powdered glass, and animal charcoal; one stratum of about half an inch thickness of finely powdered glass; upon which is a layer of about an inch and a half of well burnt animal charcoal, and over this about three quarters of an inch to an inch of more coarsely pounded glass, and over that, the usual sponge for filters. This I conceive is a mechanical as well as a chemical filter.

27. How does it act?—Very well.

28. But it does not yet detain the matter in solution to which you attribute the disagreeable smell?—No; but I believe it diminishes it.

29. Are there not natural filters which do detain matter in solution?—Yes; for instance, water which is impregnated with the water draining from bogs which is of a pale brown colour when taken up in a glass, and looks like an infusion of tea when in the river, is rendered quite colourless by percolation, through a stratum of sand and gravel, in which vegetation is going on; and whether the decolouration from the effects of vegetation, or from the peculiar composition of the filter or percolate, I am unable to decide; but I rather give evidence to the effect of vegetation, seeing that no artificially constructed filter yet made will effect the object.

Professor Hoffman, examined.

Professor Hoffman.

1. You are Principal of the College of Chemistry?—I am Professor in the Royal College of Chemistry.

2. You were educated under Baron Liebeg?—I was.

3. In the course of your operations at the College, have you had occasion to make or superintend analysis of the Thames water? and, if so, will you be so good as to communicate to the Commission a copy of the results of the several analyses?—I send with this copies of the results of these analyses.

4. At what places and at what times were the specimens taken?—It is stated in the copies of the several analyses.

5. It is presumed as a matter of course that the quality of the water of such a river as the Thames will vary at different times and seasons, according as upland floods may bring surface water, or as the river

may be left to its ordinary sources of deep springs (if such be the sources), and according to the character of the districts from which the floods may come?—It cannot be doubted that the quality of the water of such a river as the Thames must vary within certain limits, according to the seasons, and that it may be occasionally influenced by upland floods; and this influence must vary with the character of the district from which the floods may come. Professor Hoffman.

6. Will you state to the Commissioners the extent to which, from your knowledge, the analysis of river waters or springs has been attended to on the Continent, and put in evidence any information you may have collected of the results of any such analysis?—In reply to this question, I beg to offer to the Commissioners a copy of a synopsis (intended for publication in the Annual Report on the progress of Chemistry), of all the analyses of river-waters and well-waters which have been made, during 1847 and 1848, in this country, in America, and on the Continent.

7. It is presumed that the quality of a water will be affected by the extent to which it absorbs or gives out the various gases that it may come in contact with?—Most undoubtedly, especially with regard to the gases which water gives out. I may mention that I know a little river in the north of Germany, the water of which is found to be very hard when examined close to its source in the limestone. This water becomes softer and softer the further it proceeds in its course; this diminution of hardness, which has been traced by analysis, is evidently due to the gradual loss of carbonic acid, which retained a certain quantity of carbonate of lime in solution. Clark finds Watford water softens about one-fourth of a degree per day by exposure in a shallow dish.

8. In respect to the quality of the air of the atmosphere itself, it is observed that a child taken from a mountain district in the country, and placed in a close court or alley in a densely populated town-district, will lose its healthy colour, and no longer thrive at the same rate, although its condition in other respects may remain the same. Is not this a test of the difference between one atmosphere and another as decisive as litmus paper for an acid or alkaline solution?

9. Has chemistry been able to determine the agencies in local atmospheres which produce such effects as are thus universally experienced in the young, susceptible, feeble, and sickly?

Ans. to 8 and 9. It cannot be denied that the air in the close courts and alleys of a densely populated town-district produces effects upon the organism which are not observed, *e. g.*, in a mountainous country. These effects may, to a very considerable extent, be due to the difference in the physical and mechanical condition, state of motion, rapidity of change, &c., of the two kinds of air in question; nevertheless, part of these effects may, I believe, be ascribed to the presence of certain constituents which the air contains, in addition to its usual components. These constituents must be present, however, in exceedingly small quantity, for chemistry has not, up to the present moment, succeeded in isolating these substances, or characterizing them by particular reactions. As yet, in the air only the presence of oxygen, nitrogen, aqueous vapour, carbonic acid, and ammonia, has been accurately

Professor Hoffman.

established, but it has been proved that occasionally other substances must exist in the atmosphere; for, on passing the air of certain localities through concentrated sulphuric acid, the acid is found to become black; an effect which is not produced by any of the constituents mentioned above. Thus the presence of substances other than those enumerated is indicated only by their action upon the organism and upon sulphuric acid, but we are unable to say whether both kinds of atmospheric constituents are the same.

10. You must have had experience of a London fog: has chemistry the power of analyzing its constituents?—The experiment has never been tried; but, although I think that it would not be difficult to condense aqueous vapour, and to collect finely-divided carbon, and various products of the combustion of coal, from a London fog, on submitting a sufficient quantity of the foggy air to analysis, I am not prepared to say whether there are not at such periods minute quantities of certain constituents in the atmosphere, for the detection of which science is not sufficiently advanced, and which, in this respect, would resemble the additional air-constituents supposed to exist in the atmosphere of densely populated cities.

11. Since it is a matter of common experience that water absorbs a quantity of the air which sweeps over it, or in which it is confined, it would follow that it may absorb matter of which chemistry has not yet determined the essential properties?—Most of the gases having been found to dissolve to a certain extent in water,* it is very probable that the atmospheric constituents referred to are likewise soluble in water. This question, however, cannot be positively decided as long as we have not become more fully acquainted with the nature of these substances.

12. Will you state whether there are any, and what, results of chemical research available for practical guidance in respect to the collection, storage, and distribution of water?

13. Are you aware of any, and what, observations on waters of different sorts—as to their value for drinking, washing, and for culinary purposes—in Germany or other parts of the Continent?

Ans. to 12 and 13. With respect to questions 12 and 13, I beg to remark that I am not in possession of any knowledge beyond that derived from ordinary chemical experience.

The properties requisite in waters intended for drinking, washing, and for culinary purposes, vary to a very considerable extent. Whilst a certain quantity of lime and magnesia-salts will, with a few exceptions perhaps, not be found inconvenient in water intended for drinking, these salts interfere sadly with its application for washing and for culinary purposes. Again, the soft, slightly alkaline water, well calculated for the latter purposes, will be found very insipid and disagreeable when used as a drink. If the *same water* is to be used for the *three*

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* 1,000 gallons of water dissolve, at the common temperature—

46	gallons of oxygen.
25	gallons of nitrogen.
2,500	gallons of sulphuretted hydrogen.
1,000	gallons of carbonic acid.
500,000	gallons of ammonia.

different purposes, I believe that it would be advantageous to collect springs resembling in their composition as closely as possible rain-water, which is adapted for drinking, washing, and for all kinds of culinary purposes. Among various waters, containing, *cæteris paribus*, different quantities of fixed constituents, I would give the preference to the water containing the smallest amount. For the storage of the water, I would recommend cisterns of slate, and for the distribution, earthenware or glass pipes; lead being acted upon by very pure water. An article has been lately introduced under the name of Paris vitrified iron, the application of which for the distribution of water appears very promising; a series of experiments with this material are not unlikely to lead to important results.

On the Continent, the water question has been discussed far less than in this country, and I am not aware of any results which would be worth the notice of the Board.

Analysis of Thames-water.

The Thames water was analysed by Mr. F. Clark and by Mr. E. T. Bennett. The former took the water in the neighbourhood of Twickenham on the 16th December, 1847, two hours after high tide. His results are contained in "Analysis of Rain-water, River-water, and Well-water," page 4.

Mr. Bennett took the water from the middle of the river, opposite the Hospital at Greenwich, on the 1st January, 1849, at high tide. His results are given in the annexed Table:—

	Grains in an Imperial Gallon.
Sulphate of potassa	1·3710
Sulphate of soda	3·9224
Sulphate of magnesia	0·5475
Chloride of magnesium	1·1482
Chloride of calcium	1·6272
Carbonate of lime	14·3997
Silicic acid	0·7958
Phosphate of alumina (iron)	Traces.
Organic matter	4·0810
	27·8928

Free carbonic acid . . 19·8535 cubic inches in the gallon.

Analysis of Rain-water, River-water, and Well-water.

According to *R. A. Smith*, rain-water falling in towns contains organic matter exceeding usually 0·001 per cent. (in *Manchester*). Rain-water, collected after 30 hours' rain, was found to contain 0·0027 per cent. of chlorine and 0·00343 of sulphuric acid. *Smith* frequently found the rain-water alkaline, which he thinks is due to carbonate of ammonia, and the air frequently acid. Water from peaty soil contains a substance which, on burning, exhibits the odour of peat. The river *Dee*, near *Chester*, contains 25 grains of such organic matter per gallon. River-water in the neighbourhood of large towns leaves a residue which, on burning, exhibits the odour of protein-compounds

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in a state of decomposition. In well-water at *Manchester* he found as much as 14 grains of organic matter and ammonia-salts, and 70 grains of nitrates per gallon.

Ragsky has examined the water of two artesian wells in *Vienna;* (A) of that near the *Mariahilf* line, and (B) of that at the station of the *Vienna Raab* Railway. Column (C) gives an abstract of *Johnstrug's* analysis of the *Copenhagen* well-water. (A) represents the quantities in *Vienna* grains referred to 16 oz. of water; in (B) and (C) the quantities are referred to 1000 parts of water.

	A.	B.	C.
Carbonate of Lime	2·800	0·0078	2·68 to 5·13
,, Magnesia	0·694	0·0043	0·19 to 0·61
,, Soda	. .	0·6387	. .
,, Protoxide of Iron . .	0·010	0·0010	. .
Chloride of Potassium	. .	. .	0·51 to 7·21
,, Sodium	. .	0·2893	
,, Calcium	0·099	. .	. .
,, Magnesium	1·553	. .	0·26 to 0·75
Sulphate of Potassa	. .	. .	0 to 0·75
,, Lime	1·979	. .	0·09 to 0·68
Nitrate of Soda, with some Potassa .	0·977	. .	. .
,, Magnesia	1·155	. .	. .
Phosphate of Lime	. .	. .	0·07 to 0·39
Silicic Acid	0·132	0·0122	0·18 to 0·31
Loss and Organic Substance . . .	0·146	0·0237	. .
Volatile Compounds	. .	. .	0 to 0·60
Free Carbonic Acid	2·18	. .	. .

Müller has analysed the water of the river *Meuse*, of several wells in *Rotterdam*, of the *North Sea* at *Scheveningen*, of the *Rhine* near *Emmerich.* He gives the amount of fixed constituents, without stating what sort of lbs. is adopted, and in which unit the various weights are expressed; we consequently refrain from details.

Boutron-Charlard and *O. Henry* have examined the various waters which feed the public wells of *Paris.* This investigation embraces specimens of *Seine* water collected at the *Pont d'Ivry* (A), at the *Pont Notre Dame* (B), at the *Pompe du Gros Caillou* (C), at the *Pompe de Chaillot* (D), the water of the *Marne* (E), the water coming from *Arcueil* (F), the water of the *Artesian well* at *Grenelle* (G), the water of the *Canal de l'Ourcq* (H). The Table gives the number of grammes of solid constituents, and the number of litres of gas, contained in one litre of water. (*See* page 191.)

Deville has examined the composition of the following waters: of the *Garonne* near *Toulouse* (A), of the *Seine* near *Bercy* (B), of the *Rhine* near *Strasburg* (C), of the *Loire* near *Orleans* (D), of the *Rhone* near *Geneva* (E), of the *Doubs* near *Rivotte* (F), of the well-water of *Mouillère* (G), of *Billecul* (H), of *Arcier* (I), and of *Bregille* (K) near *Besançon*, of *Suzon* (L) near *Dijon*, and of *Arcueil* (M) near *Paris*, of the wells in the *Grand Rue* (N), the *Rue de la Prefecture* (O), and near the *Faculté des Sciences* (P) at *Besançon.*

He determined not only the composition of the whole water, but also that of the precipitate produced by one hour's ebullition, and of

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	A.	B.	C.	D.	E.	F.	G.	H.
Bicarbonate of Lime	0·132	0·174	0·229	0·230	0·301	0·158	0·[illegible]292	0·158
,, Magnesia	0·060	0·062	0·075	0·076	0·120	0·060	0·0[illegible]92	0·075
,, Potassa	..	..	..	..	..	Trace.	0·0100	..
Sulphate of Lime	0·020	0·039	0·040	0·040	0·022	0·138	..	0·080
,, Magnesia } ,, Soda	0·010	0·017	0·027	0·030	0·018	0·072	..	0·095
,, Potassa	..	..	..	..	..	..	0·0320	..
Chloride of Calcium } ,, Magnesium } ,, Sodium	0·010	0·025	0·032	0·032	0·020	0·081	..	0·113
,, Potassium	..	..	..	..	..	..	0·0570	..
Potassa-Salts	Trace.	Trace.	Trace.	Trace.	..	..	..	..
Alkaline Nitrates	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	..	Trace.
Silicic Acid	0·008	0·014	0·023	0·024	0·030	0·018	0·0100	0·069
Alumina							0·0020	
Sesquioxide of Iron } Organic Matter	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
Total Amount of fixed Constituents	0·240	0·331	0·426	0·432	0·511	0·527	0·1494	0·590
Atmospheric Air	0·003	0·003	0·004	0·003	Trace.	0·004	..	..
Free Carbonic Acid	0·013	0·014	0·014	0·013	0·013	0·070	..	..

the soluble and insoluble portion of the residue left on evaporation. We here give his results respecting the composition of the water as a whole. The following Table represents in milligrammes the amount of fixed constituents, and in cubic centimetres that of the free gases (assumed to be dry), of a temperature of 0° and a pressure of 760 milligrammes, contained in 10 litres of water. The same holds good for *Grange's* analysis of the water of the *Isere* near *Grenoble*. *Grange* has examined, moreover, the water of several brooks of the *Isere* valley. He gives the composition of these brooks, which run over soils of varying composition in various stages of their course, and discusses the depeudance of the amount of fixed constituents on the geological formation of the soil; he adduces the presence, in spring-water, of magnesia salts as the cause of goitre and rhachitism, &c.

	A.	B.	C.	D.	E.	F.	G.	H.
Silicic Acid	401	244	488	406	238	159	250	246
Alumina	..	5	25	71	39	21	43	43
Sesquioxide of Iron	31	25	58	55	..	30	..	..
Carbonate of Lime	645	1,655	1,356	481	789	1,910	2,573	2,561
,, Magnesia	34	27	50	61	49	23	..	46
,, Protoxide Manganese	30	..	..	..	..	..	..	..
Sulphate of Lime	..	269	147	..	466	..	51	100
,, Magnesia	..	..	..	..	63	..	..	..
Chloride of Calcium	..	..	..	..	..	..	7	71
,, Magnesium	..	..	..	..	..	5	20	40
,, Sodium	32	123	20	48	17	23	..	..
Sesquicarbonate of Soda	65	..	..	..	..	..	..	..
Carbonate of Soda	..	..	..	146	..	..	..	..
Sulphate of Soda	53	..	135	34	74	51	..	..
,, Potassa	76	50	..	..	..	..	..	..
Nitrate of Potassa	..	..	38	..	40	41	23	44
,, Soda	..	94	..	..	45	39	118	156
,, Magnesia	..	52	..	..	..	..	..	..
,, Lime	..	..	..	..	..	..	..	..
Silicate of Potassa	..	..	..	44	..	..	..	..
Total Amount of fixed Constituents	1,367	2,544	2,317	1,346	1,820	2,302	3,085	3,307
Free Carbonic Acid	170	162	76	18	79	178	390	267
Nitrogen	79	120	159	} 202	{ 184	182	154	101
Oxygen	157	39	74		84	95	64	49

Professor Hoffman.

	I.	K.	L.	M.	N.	O.	P.	Q.
Silicic Acid	390	348	152	306	314	297	551	37
Alumina	90	65	10	53	94	62	39	35
Sesquioxide of Iron	..	..	..	..	..	..	..	..
Carbonate of Lime	2,139	2,079	2,300	1,990	2,156	2,017	2,331	1,037
,, Magnesia	78	43	38	82	85	207	76	25
,, Protoxide Manganese	..	..	..	..	..	..	..	..
Sulphate of Lime	..	74	..	1,638	802	662	2,660	208
,, Magnesia	..	..	..	..	..	..	..	302
Chloride of Calcium	..	11	..	..	..	238	199	..
,, Magnesium	..	27	..	166	72	255	615	7
,, Sodium	20	..	32	376	557	15	..	36
Sesquicarbonate of Soda	..	..	..	..	..	..	..	..
Carbonate of Soda	69	..	21	..	..	..	..	..
Sulphate of Soda	45	..	27	54	..	..	..	} 90
,, Potassa	..	..	..	201	57	..	..	
Nitrate of Potassa	Trace.	23	27	..	899	786	535	..
,, Soda	..	48	..	..	304	870	1,229	..
,, Magnesia	..	..	..	570	..	..	..	..
,, Lime	..	81	..	..	..	..	381	..
Silicate of Potassa	..	..	..	..	..	..	..	..
Total Amount of fixed Constituents	2,831	2,799	2,607	5,436	5,340	5,410	8,616	1,876
Free Carbonic Acid	208	226	237	256	202	263	350	110
Nitrogen	153	142	167	127	171	157	202	} 30
Oxygen	59	72	75	50	43	41	44	

Clark has examined the *Thames* water near *Twickenham* (A); *Abel* and *Rowney* that of the artesian well in *Trafalgar-square*, in *London*, which comes from a depth of 400 feet, and is remarkable for its softness (B). In the following Table we give the quantity of fixed constituents, expressed in grains and in grammes, the amount of free carbonic acid, expressed in English cubic inches and in cubic centimetres, contained respectively in an imperial gallon and in 10,000 grammes of water. In the analysis of a well-water of *Wolverton* (C), by *Giles*, and of the river *Exe*, near *Exeter* (D), the quantities are expressed in grains, and referred to one gallon (70,000 grains).

	A.		B.		C.	D.
	Grains.	Grammes.	Grains.	Grammes.		
Specific gravity	1·0003	1·0003	1·00009	1·00009	1·00067	..
Sulphate of Potassa	0·66794	0·09542	13·6710	1·95300	..	
,, Soda	2·00011	0·28573	8·7493	1·24990	14·324	0·080
,, Lime	0·45073	0·06439	..	..	..	3·040
,, Magnesia	..	..	..	..	..	0·160
Chloride of Magnesium	..	..	..	..	..	0·640
,, Calcium	1·75021	0·25003	..	..	..	Trace.
,, Sodium	..	..	20·0585	2·86550	6·003	4·240
Carbonate of Lime	12·75946	1·82278	3·2550	0·46500	10·9650	0·896
,, Magnesia	1·02711	0·14673	2·2540	0·32200	2·319	0·064
,, Soda	..	..	18·0488	2·57840	6·576	..
Nitrate of Lime	..	..	..	..	..	0·160
Phosphoric Acid	Trace.	Trace.	..	..	..	..
Phosphate of Soda	..	..	0·2910	0·04160	..	..
,, Lime	..	..	0·0340	0·00486	..	Trace.
,, Iron	..	..	..	..	0·540	..
Crenate of Magnesia	..	..	..	..	..	Trace.
Crenic Acid	..	..	0·1372	0·01960	..	..
Apocrenic Acid	..	..	0·0937	0·01410	..	..
Organic Matter	3·48019	0·49717	0·6720	0·09600	2·850	1·60
Sesquioxide of Iron	Trace.	Trace.	..	..	..	..
Alumina	Trace.	Trace.	..	..	0·260	..
Silicic Acid	0·27314	0·03902	0·9710	0·13100	0·200	Trace.
Loss	0·07106	0·01158	1·1644	0·17404	..	..
Total Amount of fixed Constituents	22·48995	3·21285	69·4050	9·91500	44·032	10·880
Free Carbonic Acid	14·233	51·34	8·423	303·9	..	..

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Bull has examined the waters, remarkable for their hardness, of various wells at *Hartford* in *Connecticut*, in *North America*. He found in 10,000 parts, by weight of water :—

	A.	B.	C.	D.	E.
Specific Gravity	1·0008	1·0004	1·0001	1·0008	1·0011
Sulphate of Lime	0·69	0·61	0·30	0·79	0·89
Chloride of Magnesium	0·41	0·23	0·22	0·81	0·41
,, Calcium	1·12	0·70	0·39	. .	1·79
,, Sodium	1·91	. .	. .	. .	2·67
Carbonate of Lime	2·25	1·31	0·21	1·48	. .
,, Magnesia	0·19	. .	. .	. .	1·57
Crenate of Magnesia	. .	0·13	0·76	0·44	. .
Carbonate of Soda, equivalent to Crenate	0·22	1·09	1·19	2·35	2·67
Sesquioxide of Iron Alumina	0·04	0·38	. . 0·14	0·04	Trace.
Lime	. .	. .	. .	0·23	. .
Silicic Acid	0·18	0·60	0·14	0·04	0·10
Loss	0·10	0·46	. .	0·18	1·78
Total Amount of fixed Constituents	7·11	5·51	3·31	6·36	11·82

Answers to Questions put to R. Phillips, Esq. Mr. Phillips.

1. You are one of the Government chemists attached to the department of the Geological Survey?—I am chemist and curator at the Museum of Practical Geology, which is a Government establishment.

2. In the course of your practice, public or private, have you been called upon to analyze Thames water?—I have been frequently so called upon.

3. How often?—I cannot answer this question without referring back to the operations of many years, which I am apprehensive I may be unable to find an account of.

4. Will you be so good as to state whether you have found the results to differ very materially at different places and times?—I think not very materially, unless the water be taken very high up the river. This will appear by the result of the analyses, which I will now state :—

The first analysis of which I retain a record was reported to the Commissioners of 1827.

The water was taken from the north reservoir at Paddington, in May, 1827.

An imperial gallon gave $\frac{4}{10}$ of a grain of mechanically suspended impurity.

The saline contents of a gallon, obtained by evaporation to dryness, weighed 24·4 grains, consisting of—

Carbonate of lime	16·4 grains
Sulphate of lime	6·0 ,,
Common salt	2·0 ,,
	24·4 ,,

Mr. Phillips. — I may here remark, once for all, that Thames water also contains minute traces of magnesia, silica, oxide of iron, and organic matter. The gallon is in all cases the *imperial*.

Thames Water taken from the House Cistern of the Burlington Hotel when the Water was on, May 1827.

A gallon gave 0·4 grain of suspended impurity.
A gallon, evaporated to dryness, left 22·8 grains of residue.
The 22·8 grains consisted of—

Carbonate of lime . .	15·8 grains
Sulphate of lime . . .	5·6 ,,
Common salt . . .	1·4 ,,
	22·8 ,,

Thames Water taken from the Lock above the Waste Weir at Teddington, April 29, 1827.

A gallon gave 0·3 grain of suspended impurity.
A gallon, evaporated to dryness, left 17·4 grains residue.
The 17·4 grains consisted of—

Carbonate of lime . .	14·8 grains
Sulphate of lime . . .	1·2 ,,
Common salt . . .	1·4 ,,
	17·4 ,,

It will be observed that this water, taken far up the river, contained only about two-thirds as much saline matter as that from the north reservoir at Paddington.

Thames Water from the West Middlesex Water-works, brought to me by a Messenger from the Office of Woods.

A gallon, evaporated to dryness, left 20·4 grains residue.
The 20·4 grains consisted of—

Carbonate of lime . .	15·0 grains
Sulphate of lime and common salt	5·4 ,,
	20·4 ,,

N.B. The common salt may generally be considered as equal to about one-half the quantity of sulphate of lime.

Thames Water from the Grand Junction Source, reported to the Lords' Committee, March 1840.

A gallon gave 0·28 grain of suspended impurity.
One gallon, evaporated to dryness, left residue 19·4 grains.
The 19·4 grains consisted of—

Carbonate of lime . .	16·0 grains
Sulphate of lime and common salt	3·4 ,,
	19·4 ,,

Thames Water delivered in London by the Grand Junction. Mr. Phillips.

A gallon, evaporated to dryness, left residue 19·8 grains.
The 19·8 grains consisted of—

Carbonate of lime . .	16·0	grains
Sulphate of lime and common salt	3·8	,,
	19·8	,,

Thames Water from the River opposite the Works of the West Middlesex.

A gallon gave very nearly 0·3 grain of suspended impurity.
A gallon gave, by evaporation to dryness, 18·6 grains residue.
The 18·6 grains were composed of—

Carbonate of lime . .	16·9	grains
Sulphate of lime and common salt	1·7	,,
	18·6	,,

Thames Water from the West Middlesex Water-works.

A gallon gave nearly 0·19 grain of suspended impurity.
A gallon, evaporated to dryness, left 19·8 grains residue.
The 19·8 grains were composed of—

Carbonate of lime . .	15·5	grains
Sulphate of lime and common salt	4·3	,,
	19·8	,,

Chelsea Water-works, taken from the River opposite.

A gallon gave of suspended impurity 0·66 grain.
A gallon, evaporated to dryness, left 19·4 grains of residue.
The 19·4 grains gave—

Carbonate of lime . .	16·5	grains
Sulphate of lime and common salt	2·9	,,
	19·4	,,

Chelsea Water-works Water as it came in, and not allowed to settle.

A gallon gave nearly 0·1 grain of suspended impurity.
A gallon yielded, by evaporation to dryness, 19·8 grains residue.
The 19·8 grains were composed of—

Carbonate of lime . .	16·4	grains
Sulphate of lime and common salt	3·4	,,
	19·8	,,

Thames Water, Windsor, taken above the Town.

A gallon gave, by evaporation to dryness, 14·80 grains residue.
The 14·80 grains consisted of—

Carbonate of lime . .	10·26	grains
Sulphate of lime . . .	3·04	,,
Common salt . . .	1·50	,,
	14·80	,,

Mr. Phillips. It is to be observed that the water taken above Windsor contains less saline matter than that taken from any other place lower down the river.

5. Will you state the general characters of the specimens you analyzed, as applicable, so far as might be determinable by analysis, to domestic purposes?—Supposing always that the water, either by subsidence or filtration, is rendered clear before use, I cannot see that there is any purpose whatever to which Thames water is not applicable. Like other water which receives large quantities of animal and vegetable matter in a state of decomposition, it will of course undergo the putrefactive fermentation, but this is quite extraneous to the intimate nature of the water.

Thames water is scarcely to be reckoned a *hard water*, and as the principal substance which renders it hard is *bi-carbonate*, and not *sulphate of lime*, the former is decomposed, and the water rendered softer by boiling; whereas, if *sulphate* of lime were present in large quantity, it would, within certain limits, become harder by boiling. I therefore consider Thames water as applicable to all purposes, whether manufacturing or domestic, though it must be admitted that, like river water in general, it is flat when it is drank.

6. What was the analysis of the Thames water which you were requested to make for the Lambeth Water Company?—The Thames water which I analyzed for the Lambeth Water Company was taken from Thames Ditton. This water was free from smell or taste, and although not perfectly clear, yet by standing it becomes as bright as if it had been filtered.

A gallon gave, by evaporation to dryness,—

Carbonate of lime . . .	12·34	grains
Sulphate of lime	1·82	,,
Carbonate of magnesia . . .	1·84	,,
Sulphate of magnesia . . .	0·90	,,
Chloride of sodium, with a trace of chloride of potassium .	1·80	,,
Silica	1·10	,,
Organic matter, with a very minute trace of oxide of iron .	0·65	,,
	20·45	,,

I also analyzed, but not minutely, the water supplied by the Lambeth Company, taken from the main near the Obelisk, St. George's Circus. A gallon gave 22 grains of residue by evaporation, which appeared to contain a little more organic matter than that of the water from Thames Ditton, and on standing it did not so readily become clear.

7. What was your opinion of the water as respects salubrity?—I consider the water from Thames Ditton, and also from Windsor, as perfectly salubrious, and though Thames water when less clear than these is not so agreeable to drink, I do not think that any of the specimens which I have examined can be considered as positively insalubrious.

9. Have you not had occasion to analyze any hard drainage waters or shallow spring waters?—Several years since I examined, but did

not analyze, the water of a constantly running spring at the Military College near Bagshot; it was remarkably pure. Mr. Phillips.

I have likewise examined the spring water at Ascot; it is remarkably pure.

One gallon yields, by evaporation, 6·4 grains.

These 6·4 grains consist of—

Carbonate of lime and common salt .	5·0	grains
Silica	1·0	,,
Magnesia, a minute trace of oxide of iron, and vegetable matter .	0·4	,,
	6·4	,,

I have also analyzed the water at Claremont. I have not been able to lay my hand on the results at present. To the best of my recollection it greatly resembled that from Ascot, and at any rate it was remarkably pure.

12. Have you had any occasion to examine any specimens of Artesian-well water?—Some years since I made a general examination of them, but they have since been more minutely analyzed by several persons.

13. Besides the Thames water, have you analyzed any of the streams contributing to the Thames?—*I have analyzed the water of the Colne.*

A gallon gave 21·3 grains of residue by evaporation.

These 21·3 grains consisted of—

Carbonate of lime	18·1	grains
Sulphate of lime and common salt .	3·2	,,
	21·3	,,

The suspended impurity was 0·1 of a grain in a gallon.

I may here repeat the statement which I have already made with respect to Thames water, that the water of the Colne contained also traces of magnesia, silica, oxide of iron, and organic matter.

Water from the Otterpool, or Main Spring, just above Bushy Park.

A gallon gave by evaporation 21·3 grains.

These 21·3 grains contained—

Carbonate of lime	18·8	grains
Sulphate of lime and common salt .	2·5	,,
	21·3	,,

It also contained traces of the same substances as above mentioned with respect to the water of the Colne.

The suspended impurity was nearly 0·14 of a grain in a gallon.

Water from the Main Stream of the Valley, or the Spring which supplies the Colne.

One gallon gave by evaporation 21·8 grains.

These 21·8 grains were composed of—

Carbonate of lime	19·3	grains
Sulphate of lime and common salt .	2·5	,,
	21·8	,,

Mr. Phillips. The mechanical impurity amounted to 0·2 of a grain in a gallon.

It also contained traces of the substances found in the above described specimens.

I have also analyzed the spring water at Claremont, which rises in a pond at about two miles distance from the house.

A gallon of this gave by evaporation 5·7 grains.

These 5·7 grains consisted of—

Common salt	2·7 grains
Sulphate of lime, with traces of silica, oxide of iron, and organic matter	3·0 ,,
	5·7 ,,

It may be proper to add that on account of the purity of the water of Bagshot, Ascot, and Claremont, it was found that the lead pipes which conveyed and the cisterns which contained it were most injuriously acted upon by it.

GEOLOGICAL.

Memorandum of Robert Austen, Esq., Chilworth Manor, Guildford, Surrey.

Mr. Austen. My Lords and Gentlemen,

You require me to furnish you with some notes on the area of the Bagshot sands, as a source of water supply for London. The points to which you more particularly call my attention in the memodum with which you furnished me yesterday are these—

§ 1. The probable limits of the gathering ground.

§ 2. The points where the water specimens had best be taken.

To these, therefore, I shall confine myself, in the present instance—

§ 1. The Bagshot sands, as a continuous series of beds, extend from Esher to Strathfieldsaye, east and west, about 30 miles. Their width is variable; they occur north of Virginia Water, and their most southern point is on the summit of the high ground above Farnham. If we estimate them to have a mean breadth of 10 miles, they will cover an area of 300 square miles.

The composition of the beds of this series is remarkably uniform.

a. The upper portion consists of pure silicious sands. This division attains its greatest thickness about the north and east portion of the mass, as at Bagshot Heath, Chobham Ridges, Romping Downs, Finchhampstead Ridges, Hartford Bridge Flats. These sands are from 200 to 300 feet in thickness.

b. Beneath these sands is a retentive stratum of marsh and clay, varying from 5 to 15 or 20 feet in thickness.

c. The lowest portion consists of white and pale yellow sands, purely silicious for the most part, the subordinate argillaceous strata being at the eastern portion of the map.

§ 2. Over the areas of the upper and lower sands much rain-water is absorbed as fast as it falls. That of the upper sands is thrown out, and collected over the surface of the retentive stratum, No. 2. At the junction of the two all the streams and streamlets take their rise, and

this same retentive stratum, where denuded, supports the water courses and ponds of the district. Mr. Austen.

Water also collects on the surface of the upper and lower sands, where argillaceous beds occur; some portion of these areas might, therefore, be made available; at present the greater portion sinks away, till it meets with the next water level, held up by the London clay, on which the whole of the Bagshot series rests.

As the arrangement of the strata in the east, south, and west is basin-shaped, few or no springs are thrown out along the edge of the mass on these sides, so that the accumulation of water is inwards.

The ridges of Esher and Claremont may almost be considered as outlying masses, cut off by the course of the river Mole. The drainage from this portion is thrown out partly in Ditton Marsh, where specimens of the water can be obtained.

On the west end of the mass the Blackwater cuts off a large portion, and carries away the drainage to the west and north.

From Ash to East Hampstead a range of high hills belonging to the upper sands (Ash Common, Romping Downs, Chobham Ridges, East-hampstead Plain), form a parting ridge between the drainage of the Blackwater and that which flows towards the river Wey. Being,

My Lords and Gentlemen,

Yours very obediently,

ROBERT W. AUSTEN.

To the Commissioners of the General Board of Health.

MY LORDS AND GENTLEMEN,

SINCE I communicated to your Board a memorandum respecting the situation and extent of an area of uncultivated land, consisting of clean silicious sands, and calculated to afford surface-water in a state of purity, I have again gone over the area with Professor Ramsay, of the Geological Survey, for the purpose of pointing out to him that the tract in question presented very many conditions of first importance towards the collecting and storing of water in large quantities.

As Professor Ramsay was personally unacquainted with the district, I was anxious that the description I had given to your Board should be confirmed by some independent and competent authority; and I, therefore requested, and had the advantage of, Mr. Prestwich's company, whose geological inquiries have given him a most thorough acquaintance with the mineral structure of the Bagshot area.

This survey has tended to confirm very strongly my first impression, that the area I have laid down in the accompanying sheet of the Ordnance survey, and which is the same as that which I pointed out on the first day on which I attended your Board, is one which is most deserving of your attention.

It will be seen that the water supply is proposed to be taken exclusively from the elevated ground north of Farnham, from the Chobham Ridges, from the Romping Downs, as well as from the high land extending from Bagshot Heath to the Fox-hills, near Chertsey, the whole of which districts belong to that division of the Bagshot sands, which constitutes their upper portion, and whose composition was explained in the memorandum above alluded to.

Mr. Austen.

The peculiar advantages which this area presents consist, first, in the circumstance that great quantities of water can be collected at once from streams of considerable volume, and before they have been rendered impure by the influx of the sewage of inhabited districts. Secondly, that the surface-drainage may be accelerated, whereby loss by evaporation will be diminished; and lastly, that it affords considerable facilities for its collection.

Reservoirs of any depth, and which might have several square miles of surface, may be formed over a stratum of retentive ground about a mile and a-half east of Chobham Place. In like manner great stores of water might be secured by the adaptation of such depressions as those at Coldingly Moor, Haythorne Moor, and one other further north, to receive the surface-water of the east of the Chobham Ridge.

Fleet Pond, which serves as the natural reservoir of the soakage from the high tract of Farnham Beacon, may be enlarged to a great extent.

I more particularly attended to the possibility of increasing the areas formed for collecting the waters of the Ash and Romping Downs, for the purposes of the high level of the Basingstoke Canal, and I pointed out that in every instance such areas might be enlarged; to this I conceive there could not arise any objections on the part of the trustees of the said navigation, inasmuch as their supply would thereby be rendered more abundant and certain.

The elevation of the whole of the district I have indicated is a most important physical feature, with reference to the supply of London.

In suggesting to your Board that the district is one most deserving of your consideration, I would point out that the amount of supply will, in a great measure, depend on a well-considered plan of surface-drainage, by means of earthen pipes, the success of which will depend on the application of physical consideration of several kinds.

The selection of specimens of water should be made only under the inspection of some person thoroughly conversant with the geological structure and mineral composition of the district, and any less accurate course would be highly dangerous, at a time when there are so many conflicting opinions and interests as to the future source of the water supply of London.

Before calling for more accurate data, as to the sufficiency of the supply which may be expected, I would recommend that the quality be ascertained, distinguishing, in every case, between surface-drainage and water of percolation. Being,

Yours very obediently,

London, March 1, 1850. ROBERT W. AUSTEN.

LETTER from A. C. RAMSAY, Esq.

Mr. Ramsay.

Geological Survey of Great Britain.
Merchlyn, Conway, North Wales,
May 25, 1850.

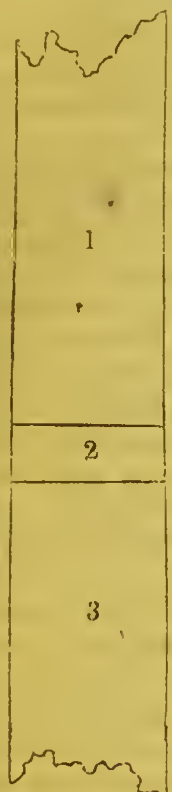
MY LORDS AND GENTLEMEN,

IN accordance with an application made to Sir Henry de la Beche last February, I proceeded with Mr. Austen to examine that district in Surrey occupied by the formation known to geologists as the Bagshot Sand, with the view of ascertaining the nature of its geological

characteristics, that in this respect you might be the better enabled to form an opinion as to the applicability of part of the area to furnish a supply of water for the use of the metropolis. Mr. Ramsay.

The length of this district is about 30 miles, and the average width of the larger portion about 12.

Its geological subdivisions are,—



Upper Bagshot Sand.

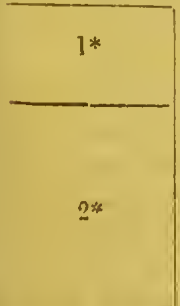
Middle Bagshot, Marls, &c.

Lower Bagshot Sand.

A general idea of the manner in which these beds appear on the surface, will be obtained from the appended horizontal section. Their mineral structure is as follows:—

1st. Upper Bagshot Sand—generally a fine light brown sand, somewhat of the colour of pale brown sugar. It appears (as far as can be determined without absolute analyses) to be nearly pure silicious sand, slightly coloured by an oxide of iron.

2nd. The Middle Bagshot beds, from 20 to 30 feet thick, generally composed of—



A green sandy bed (probably coloured by silicate of iron, and composed of the waste of the green sand of the chalk formations.)

White and pale yellow foliated marls.

3rd. Lower Bagshot Sand—mostly silicious sand, of somewhat similar texture to the Upper Bagshots, and darker in colour.

The Middle Bagshots (2), form an irregular and generally narrow band, resting on and contained within a wide area composed of the

Mr. Ramsay. lower sands. The Upper Bagshot Sand, for the most part, occupies the higher grounds within this band, such as Romping Downs, Chobham Ridges, &c., &c. For these and other physical reasons (such as its waste character, &c.), it would probably be for the most part desirable to employ the area contained within the circumference of the Middle Bagshot marls for the collection of water from the surface.

The whole series is often obscured by a superficial covering of loose sand and gravel, varying in thickness from a few inches to 20 or 30 feet, and this in the higher waste grounds is generally overgrown by a thin covering of heath. As far as I am aware no deep extensive mosses exist, or are common in the district.

Owing to the incoherent texture of the Upper and Lower Bagshot Sands, they are easily percolated by water, so that a large proportion of the rain that falls on the district must, necessarily in the first instance, be absorbed. This circumstance is rendered apparent by the fact that the smaller valleys branching out on either side of Chobham Ridges were, when visited by me, destitute of brooks. The water so absorbed is, however, checked in its downward course by the Bagshot marls (2), and when the disposition of the strata is favorable, it is thrown out to the surface at the junction of these marls with the Upper Sands (1), forming a series of springs round the retentive marly outcrop, and frequently collecting in pools of considerable area when partially intermingled with the surface drainage. (See Appendix, diagram No. 2).

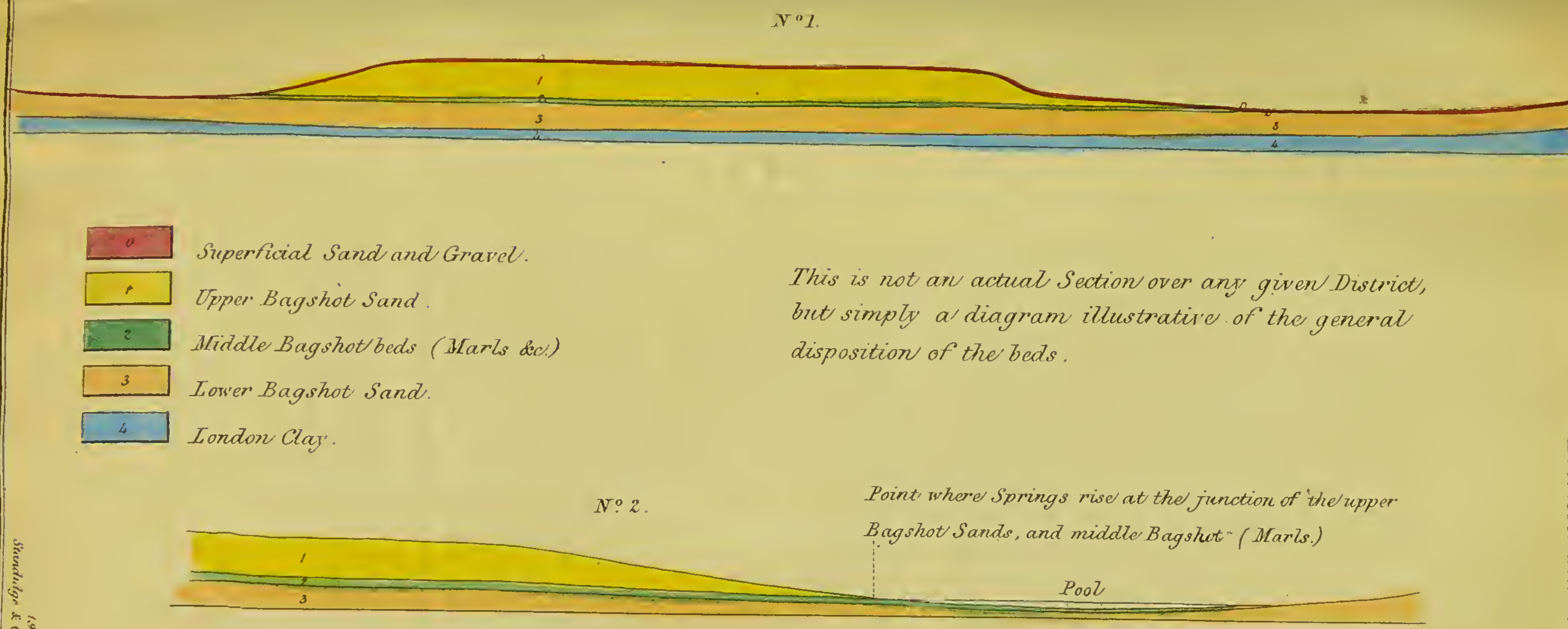
Notwithstanding the apparently purely silicious nature of the Upper Bagshot Sand, experience nevertheless shows, that in wells sunk in it, the water attains a considerable degree of hardness.

This fact was stated to me by Mr. Prestwich, whose knowledge of the geological structure of the country is exceedingly minute; and the circumstance was further corroborated by the practical experience of the landlord of the "Tumble-Down-Dick," who was in the habit of sending his horses to water at the neighbouring pool, in consequence of their being griped by his well water. This hardness must arise from the diffusion of carbonate of lime throughout the sand in quantity, which though too minute to be detected in ordinary specimens, is yet sufficient to affect the rain water percolating a sufficient area and depth. As might, under these circumstances, be expected, the springs that break out at the junction of the Upper (1) and Middle Bagshot beds (2) are also somewhat hard, and sometimes possess a chalybeate taste, the latter quality being probably induced by the percolation of water through the green sand which forms the upper bed of the Middle Bagshots. (See 1*, above.)

Nevertheless the water of all the pools visited by me (viz. Mitchetpool, Wharf-pond, Fleet-pond, Flutters-hill-pond, Gracious-pond, &c.) seems (as far as could be judged on the spot without the means of absolute testing) to be of soft quality, and it would therefore appear that in the main the pools are principally replenished by surface drainage. They were also invariably sweet and pleasant to the taste, altogether different from any of the ordinary London waters with which I am acquainted, and reminding me in this respect of the pure waters of North Wales.

The surface sand and gravel which covers the larger part of this district is, in a great measure, composed of the detrital waste of the

Professor Ramsay's Report.



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Standidge & Co. Litho Old Jewry

underlying beds of Bagshot sand; and, from its apparent quality, the *surface* drainage might be expected to be generally free from calcareous impurities, any little lime that may once have been intermingled with the surface detritus, having probably long since been carried off in solution. Mr. Ramsay.

The summit level of the canal at Wharf-pond (which is fed by the overflow of the canal), should afford a perfect test of the quality of the surface drainage of the district, the canal being there necessarily exclusively supplied with water from that source. It appeared to me that it did not differ in quality from the water of the other pools to which I have already alluded.

The entire area of the Upper Bagshot Sand is probably somewhat between 80 and 100 square miles. The average quantity of water now carried off in streams from this area, and any portion of the Lower Bagshot Sands that may be considered available; also the proportion of this district that may be available for the increased collection of water by surface drainage, together with the facilities for increasing the areas and depth of pools, &c., where it may be collected, would be easily ascertainable in the event of the execution of accurate topographical and other surveys of the district. These being purely engineering points, the nature of my investigations, and my necessarily limited stay on the ground, did not permit me to form any precise opinion regarding them.

I have the honor to be,
My Lords and Gentlemen,
Your most obedient servant,
ANDREW C. RAMSAY.

To the General Board of Health,
Gwydyr House, Whitehall.

MISCELLANEOUS.

J. M. Paine, Esq., of Farnham, examined.

What is the population of the town of Farnham?—The town has a population of about 3,500; the parish a population of 7,000. Mr. Paine.

How many houses are there in the town?—740.

How many houses do the Water Company supply?—116; but the poor people have the water for nothing, in any quantity they please, from their neighbours.

What are the terms of supply?—I will put in the following table:—

FARNHAM WATER COMPANY.

Terms for supplying the Inhabitants of Farnham with soft Water.

For ordinary Domestic Purposes.

	Per Quarter. *s.*	*d.*
Houses of the first class	5	0
,, second ditto	4	0
,, third ditto	3	0
,, fourth ditto	2	0

And where water is required for the purpose of domestic brewing or

Mr. Paine. washing, or for a water-closet, an additional fourth part of the first charge, according to the class of the house, for each purpose.

Public brewers 25*s*. per annum, and for every additional house for the sale of beer supplied by them 15*s*. more, beyond the ordinary class charges for domestic purposes and washing.

Licensed victuallers 25*s*. per annum for brewing, beyond the class charges for domestic uses, and washing and water-closets; and 20*s*. for yard purposes—first class, 7*s*. second class, and 5*s*. third class.

Maltsters 25*s*. per annum for each malt-house.

Washing-women 20*s*. per annum.

All water-rents to be payable quarterly, and in advance, and each consumer to sign an undertaking to abide by the terms of the Company.

WM. MASON,

15*th August*, 1836. *Secretary and Acting Manager.*

At this rate of charge the Company now receives 5 per cent. dividend per annum on the total outlay.

Farnham is situated on the Chalk, is it not?—The greater part of the town of Farnham is below the "Chalk," it being situated upon a bed of gravel lying upon the upper part of the "Lower Green Sand." The parish of Farnham comprises the whole of the chalk formation, together with part of the Lower Green Sand on the south, and the London clay on the north.

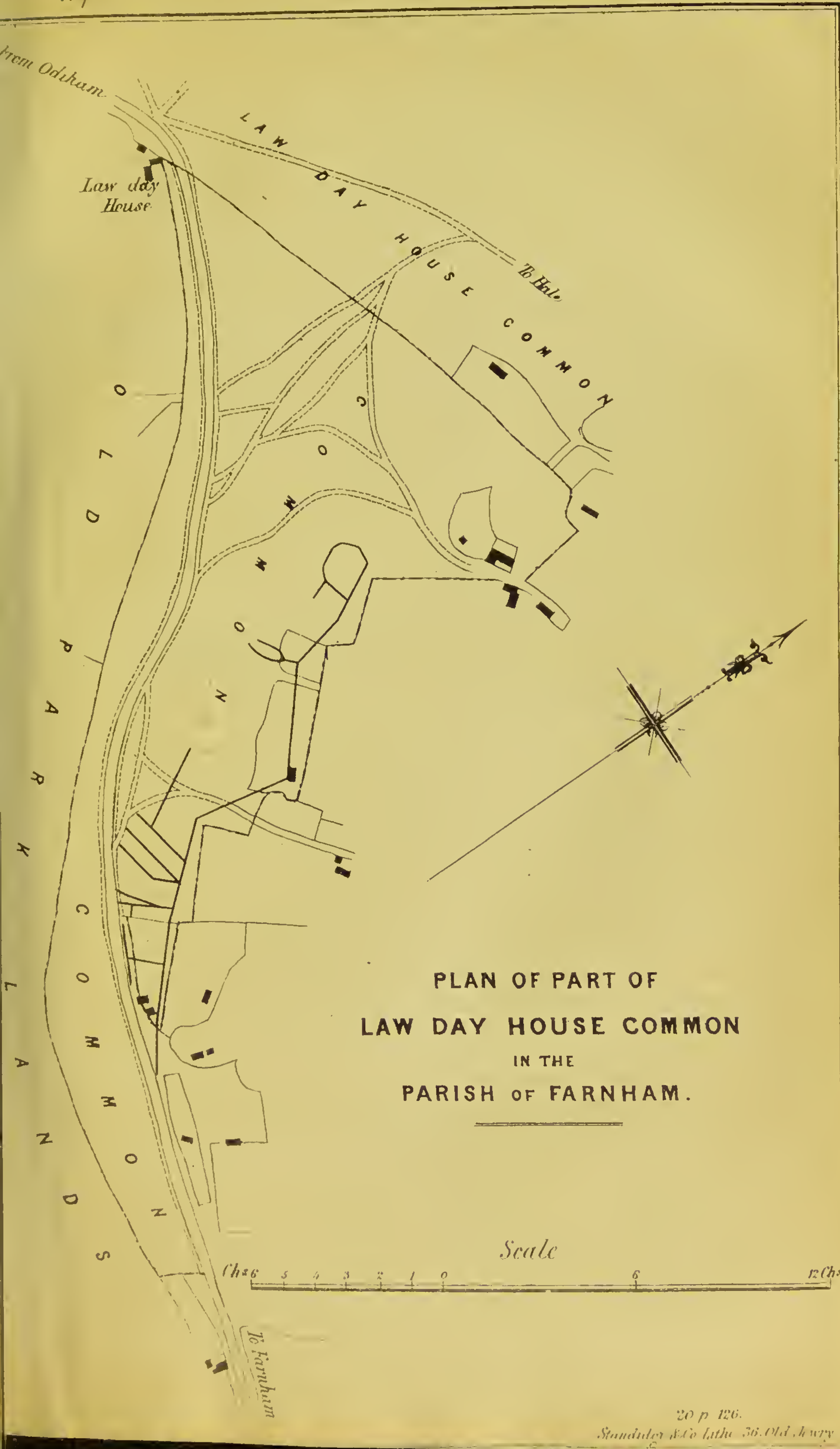
Was it not the original source of the supply of water for the town?—The town was always abundantly supplied with good hard spring-water, obtained from wells. This supply, of course, still remains.

Will you describe the circumstances which led to the change of the source of supply?—Soon after the introduction of gas into the town, about 15 years since, my father and one or two other influential inhabitants thought it would also answer well to bring the soft water from the waste commons on the north of Farnham into the town, which would afford a constant supply of pure soft water to the top of every house. The project was successfully carried into execution. This water had always been used in comparatively small quantities for washing purposes from time immemorial, there being a small reservoir in the town which received the superfluity of water from the Castle, the residence of the Bishop of Winchester. From this reservoir the inhabitants were accustomed to fetch it in water-barrels. The superior properties of the water for washing purposes have therefore long been appreciated. The present supply is abundant and continuous, and might, if required, be increased to double the quantity at the expense of a few pounds.

Will you describe the nature of the ground which you have taken as a gathering ground?—A grant of 20 acres was made by the Bishop of Winchester, as lord of the manor, and a small portion of that ground, some two or three acres, were drained.

What was the condition of that ground before it was drained?—It was a peaty bog, resting on a gravelly, sandy subsoil, that again resting on a substratum of London clay. It was such a boggy or marshy surface as sportsmen would understand if it were called "snipe-shooting ground."

What sort of drains did you put in?—The ordinary earthen pipe drains. The sand is of a very loose character, so that it has frequently choked up the drains, making it necessary that two or three times they should



PLAN OF PART OF

LAW DAY HOUSE COMMON

IN THE

PARISH OF FARNHAM.

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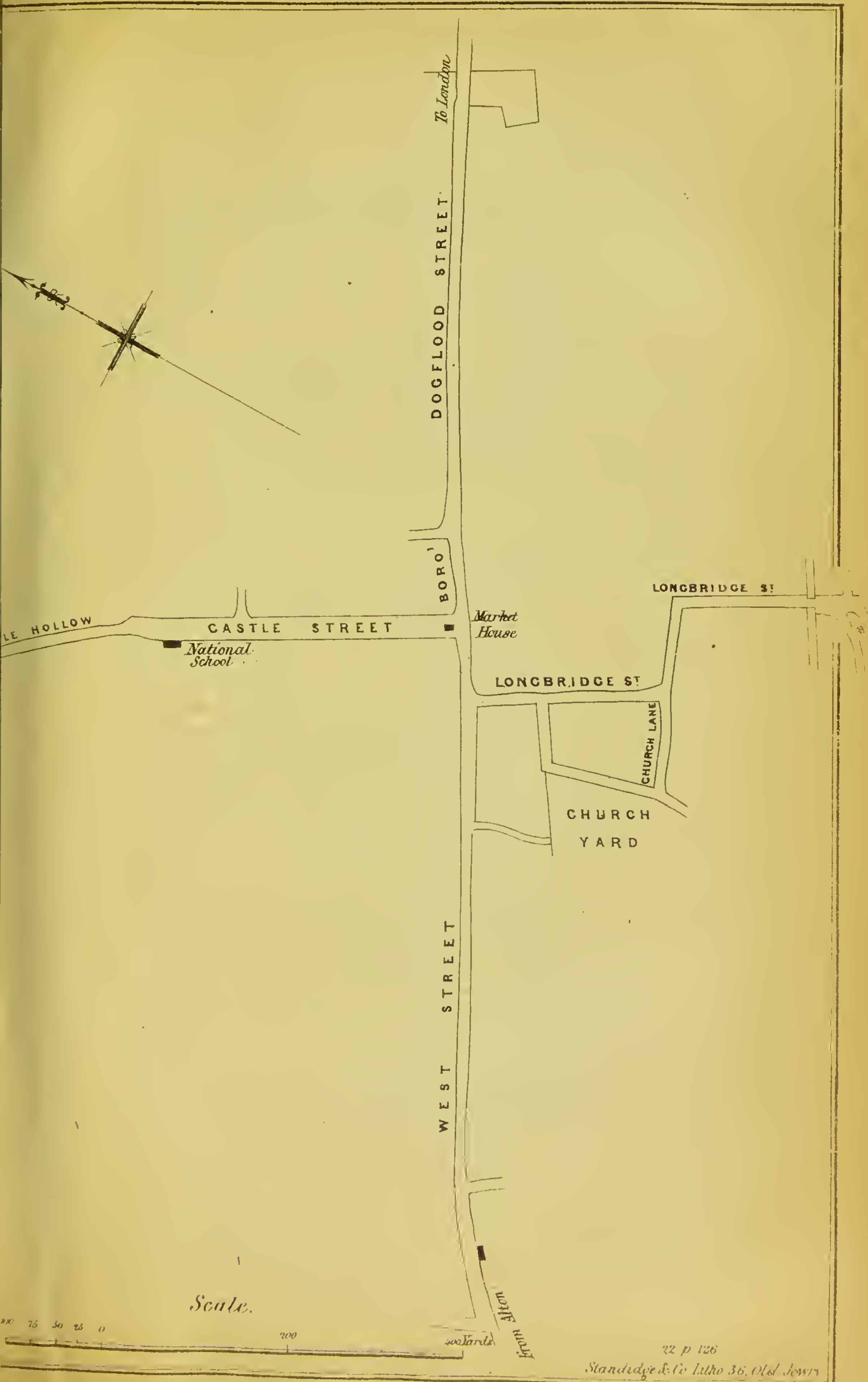

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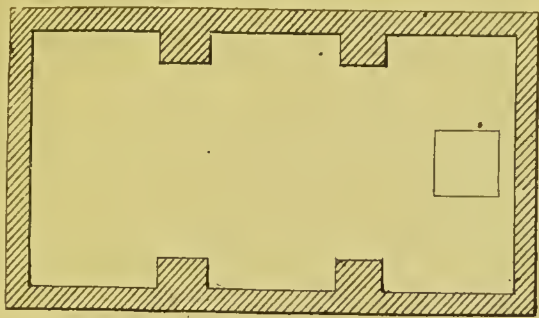
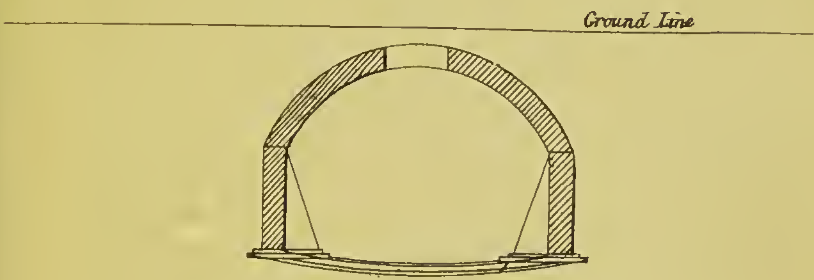
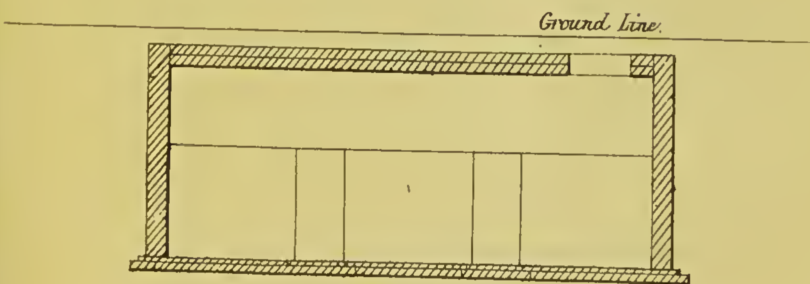


GROUND PLAN.



TRANSVERSE SECTION.



LONGITUDINAL SECTION.

Scale.

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be taken up. Subsequently, however, the main drains were formed of iron pipes, the auxiliary drains still remaining of ordinary earthen pipes. If the work had to be done again, superior earthen pipes should be used, as a better kind is required to resist the pressure. Some of the pipes had become soft as clay, having been badly burnt. Mr. Paine.

What is the size of your branch-drains ?—The branch-drains are four inches, and the trunk eight.

What is the fall ?—From the top of the common to the market-house, in the centre of the town, it is 280 feet. The water runs from this gathering-ground to a small reservoir on the common. This reservoir consists of a small tank into which the water flows, and from thence it is conveyed by iron pipes into a large tank near the Castle gate. The tank contains about 1,000 hogsheads, or 60,000 gallons.

Then those houses which require it are large houses ?—Yes; most of the cottagers have the water for nothing.

Are the wells still used in the town ?—Yes, but the water is never used for brewing or household purposes. I have never heard, however, of new wells being sunk since the waterworks were established.

Farnham lying on the chalk, and the water being very hard, did not the people find the difference between it and the soft water so important that they sent carts as far as a mile to fetch the latter ?—Yes; and the superfluous water from the Castle has been used by them from time immemorial.

Are you aware that the tea at the Bishop's Castle at Farnham has been always admitted to be of very excellent quality ?—Yes, the green tea has always been considered very excellent; and since the soft water has been introduced into Farnham, a great difference has been found in the quality, and also that a less quantity of tea has been required.

What would you describe as the effect ?—Three cups may be produced with soft water of equal strength to two with hard water, using of course the same quantity of tea.

You think that a fair popular statement ?—Yes; but there will be the difference in a superior flavour in addition, which is very distinguishable with soft water.

Do you know anything of its use in cooking ?—Nothing particular; but I know it is preferable for cooking vegetables. I only know that now hard water is never used except by those who prefer it for drinking. It may be a little colder and a little more sparkling from the carbonic acid gas.

Do you not think that the coldness of the soft water might be increased by extra care in the delivery of it ?—My impression is that this water is remarkably cold for a supply of such a description. I never taste water so cold elsewhere. This is owing to our pipes running low under ground, and to it being received in a reservoir: thus it does not imbibe any warmth from the atmosphere.

Was not this water originally collected from a spot which might have been described as "snipe-shooting ground ?"—It was.

What was the effect of drainage on the surface ?—It completely drained it.

Taken from the surface originally, what was its appearance ?—Very similar to what I have observed the Blackwater River to have: it had a brownish appearance; but now, when it is obtained from under the surface, it comes out quite clear; and that induces me to believe that

Mr. Paine. water obtained from under drainage would get rid of all vegetable impurity and come up perfectly clear.

The Farnham water was first noticed, was it not, by Professor Way from its pureness?—Yes. He was performing some experiments, for which he wanted distilled water. I directed his attention to our soft water, which surprised him by its purity. He tried it, and found it to be nearly as pure as distilled water, and it answered the purpose for which he required it.

Then this pipe-drainage has not only collected the water in greater quantity and brought it to this state of purity, having no taste or colour left, but it has also altered the surface of the ground, too?—Yes; and it has rendered the ground fit for cultivation which was previously unsuited for that purpose. Some is in grass, and other portions are used as garden-ground.

Have you observed anything to induce you to believe that the same results might not be obtainable from an extension of subsoil or agricultural drainage over the whole of this district?—No; we have specimens of water taken a mile apart, and precisely the same in character.

At what points was this water taken?—From three points; one from which the Bishop's supply is taken, and from two other places on either side, each about half a mile from the other. All the waters were equally pure.

For how many houses does this drainage of two acres give you a supply?—For 116 houses, night and day; and they do not use half the supply that is obtained; and the addition of a drain from one point might, for an outlay of 10*l.*, give double the quantity we now have, if necessary.

Have you met with any instances of the soft water passing over chalk becoming hard in the course of a short distance?—Yes; when it passes through about a quarter of a mile of chalk it becomes intensely hard. We have an example where the soft water runs into a swallow hole into the chalk, and it rises again, about a quarter of a mile eastward, in a pond, where it comes out intensely hard. That is an instance of the hardest water we have.

Do you think that the whole surface of this district would give, acre for acre, a similar quantity to this?—No; if I were to drain the whole of the hill I would only lay pipes round the sides of the hill, and thus get the natural drainage. The water would, in fact, be naturally drained to those spots, which would be indicated by the marshy appearance of the surface.

Has there been any experience as to the effects of the water in respect to the furring of kettles?—I have inquired of the plumbers, &c., in the town, whose business it is to clean boilers, kettles, &c., and they all agree that our hard water furs very much, while the soft water from the commons scarcely leaves any fur at all. I may mention as an illustration, one of them told me that my own boiler at my late residence, which is supplied with hard pump water, requires cleansing once in three months; while that of the Bishop of Winchester, which is supplied with the "commons" soft water, does not require cleansing more than once in 13 or 14 years. In my present residence I use the soft water.

What are the results as regards brewing?—My own experience, as well as of the brewers and inhabitants generally, is decidedly in favour of the soft rather than of the hard water of the town.

Mr. Paine.

Has there been any experience also as to the effects on cattle of hard and soft water?—All farmers prefer soft water for their cattle. The people who live upon our commons state, that when their horses drink our chalk water, or the water from the River Wey, it disagrees with them, and often causes what is termed the "fret."

Then the supply to the Bishop's Palace is constant?—Yes; but it has no connexion with the town supply. It is derived from another "tapping" of the hill.

Is the water conveyed there through lead pipes?—Yes.

Your supply also is through many leaden pipes in the town?—The mains are of iron, but the pipes which convey the water into the houses are of lead.

Have you heard of any casualties from the effect of the soft water upon these leaden pipes?—I am not aware of any having happened; the supply is constant, and consequently there is no need of cisterns.

How long has the supply been in existence at the Bishop's Palace?—I should say, 200 years, or perhaps more.

How long has your own supply been in operation?—Since 1837.

You are, I believe, a native of Farnham, and acquainted as an agriculturist with all the country around?—Yes.

From how many miles of surface, as far as you have observed, can a similar supply to that of Farnham be obtained?—I should say, from a district of 15 miles in length, and varying from 3 to 6 miles in breadth, lying between Farnham and Wokingham.

Is that the white sand district?—It is commonly known as the Bagshot sands; but I must add, that when there is a great depth of sand, water is not obtainable by drainage, and it is useless to drain unless you have an impermeable sub-stratum for the drains to rest on.

Is there a great quantity thrown off the surface?—Yes, I have seen quite a river flowing from it after a thunder storm from those parts of the commons which have a sub-stratum of clay at a moderate depth.

And was that such water as would admit of filtration?—Yes, and it would thus be deprived of its vegetable peaty quality.

Might it be cleared of the peat?—If I wished to have water from off this district I should break up the heath and allow the water to go under ground and catch the water in drains, I believe it would then come out perfectly clear.

It has been stated to us by our agricultural surveyor (*Mr. Donaldson*), that this peat is so thin that it might be peeled off very easily?—Yes, it is very thin at those parts whence we obtain our supply, but between Aldersholt and Cove the Eelmore Bogs have a thickness of from 8 to 10 feet deep, but the surface of it might easily be stripped, and the peat might be sold and pay the expense of the process. From these low grounds I suspect that a large supply of water might be gathered.

Then the surface might be cleared at very little expense?—Yes, for a very few pounds indeed: about 2*l.* an acre on an average; but when the peat is deep, the expense would be more. Even then the peat would pay the expense.

Do you know whether iron is found much in the district?—Certainly not in this district, which lies on the north side of Farnham; but on the south-east, on the "Lower Green Sand," there are many beds of iron-stone.

Mr. Paine.

Have you seen any reason for believing that if the land were drained it would diminish the taint of iron if it should be found expedient to use the red sand wastes as gathering grounds?—I have seen at some six or seven miles south-east of Farnham the water come out pure from the lower green sand, but it comes through a broken-up soil of diluvial grit similar to that on the north side of Farnham, and that has also been reputed soft and useful for domestic purposes.

Have you any notion of the proportionate quantity of rain-fall which might be derived from the lands of the district under consideration?—Within the vicinity of Farnham we have a less quantity of rain than at some seven or eight miles distance. Towards Woking, in showery weather, they have much more rain than we have.

Do you, on the whole, think the estimate an unfair one that one-third the quantity of rain-fall is obtainable by draining?—I think f the subsoil prevents the permeation of the water, more is evaporated. It is impossible to lay down any general rule.

Since you have drained the portion of land for the supply of your town, does less water lie on the surface?—None is to be seen on the surface, as it goes into the drains. A great quantity of water is lost if the drains are not deep enough. If we were to put other drains underneath the present ones, we should catch much more.

Then your own view is, that your works were first rude suggestions, and might now be much improved?—Very much; they cost us 2,040*l.*, and if the work were to be done *de novo*, we might do it for 1,200*l.* and get more water.

With respect to the ground which you describe as having been in its original state a snipe-shooting ground, how much more water do you think has been obtained by drainage than could have been obtained by a discharge of mere surface water, after allowing for surface evaporation?—There is no comparison between the two, as, in the one case, we had only the water which flowed from the immediate surface, whereas, by drainage, we have obtained the water from a much larger extent of ground.

Suppose you took gaugings of the principal outfalls prior to the drainage, and those derived from the district uncultivated and unworked, for water purposes, could you, from your own observation, form any notion of the proportionate difference of that produced from the whole drained surface, compared with land in its undrained condition?—I can judge to a great extent from common observation, as the flow of water is now very much larger from the drained ground than what seemed to flow from the same spot before drainage.

Of course since the draining the water does not lodge any longer on the surface, and as the bog has entirely disappeared, all the bog evaporation must be saved?—Yes; the soil is so porous that if you drain it underneath, so as to allow the water to pass off as it falls through, very little is lost by evaporation, and I believe that kind of soil spreads over a large portion of this district of country.

Then you see nothing to effect the conclusion that by like care being extended over the whole district, some 15 miles long, to from three to six or seven miles wide (thus making some 80 square miles of gathering ground), water of a similar quality to that delivered in Farnham would be obtainable?—I think so; but I should not drain the whole surface of the district, but only those spots where water is found to ooze out at the sides of elevations.

Have you had instances of losing large quantities of water through swallow-holes?—Swallow-holes are not found in this stratum: they are numerous in this neighbourhood *below* the plastic clay which lies immediately above the chalk, and here large streams disappear beneath the surface. But a very considerable quantity of water will disappear sometimes when it passes through a bed of gravel, and will sink to a considerable depth, while it will re-appear again in land at some distance. The best plan would be to drain the outskirts of the London clay, and by that means the whole of the water would be obtained. Mr. Paine.

If there were any selection to be made, of course, from your experience, you could easily avoid particular beds of a peaty character, or where iron existed, or which might otherwise be objectionable, and only take those portions which would supply pure water?—Yes; the selection might be entirely under one's own control, by allowing no water to be gathered from these undesirable spots.

Then, with these proportions, you think it practicable to preserve the purity of the water, equal to, if not superior, to that now supplied at Farnham?—I think the whole of the hill from which we derive our small supply, would furnish a great quantity of the same kind of water, particularly on the north-west side, which already discharges a copious supply into Fleet Pond and the Basingstoke Canal; and I infer from the similarity of the super and subsoils, the same description of water might be obtained from the whole of the white-sand district in the direction of Wokingham.

Is there the same appearance of vegetation over the whole district? —Yes; and the same geological appearance.

Has not the water in the Basingstoke Canal the same peaty tinge as the water on your Farnham gathering ground, prior to drainage, had? —Yes, very much so.

Have you followed the old system with regard to the distributory apparatus?—We have simply branch service-pipes running into the houses at right angles with the mains.

What is the greatest pressure of your water in the town?—I should imagine that the larger reservoir at the castle gates is about 40 feet higher than the highest house, and the water comes out with great force at the tops of our houses, and we can throw it in a jet some 30 or 40 feet.

Have you had fires lately in the town?—We have had two fires since this supply of water, and they were both extinguished by its means; and though there was a large draught of water from our tanks on the occasion, we were not obliged to shut up the works in order to fill the reservoirs again.

As far as you have observed, the character of the soil in the district you have spoken of is similar to that from which your supply is taken?—Yes; it is a mixture of sand, gravel, and clay, resting on the London clay, and the depth varies very much.

Have you ever found trees in the pipes? Willows have sometimes been found, as you are aware, in the pipes used for agricultural drainage?—Yes.

May not this be prevented by the use of impermeable pipes within the known range of the roots of trees?—Yes. I have been accustomed to lay a bed of stones round my drains at places where they were liable to such accidents.

Mr. Paine.

It has been stated that the quantity of water is increased by wood, and that more falls on forest land than on ordinary cultivated ground? —Yes. More falls and less is lost. Mr. Lawes has made some experiments with different kinds of plants, and grasses, and evergreen-trees, the result of which shows that fast-growing plants within a limited period, such as barley, oats, and wheat, evaporate through their leaves a much larger proportion than forest trees, and that evergreens evaporate very little. The law seems to be this, that rapidity of growth is coincident with a large evaporation of water.

Therefore you infer that if land is cultivated for corn land more water is taken from the soil than under heath cultivation or the growth of fir-trees?—Yes.

Would you not be afraid of taking a portion of the water from ground used as garden-ground?—No, not at all, if there is sufficient clay in the soil to absorb the ammonia. I have some clay soil of my own, where I have put a large quantity of guano; but the water flowing from my drains is quite free from ammonia.

Then you would not be afraid of the quality of water obtainable by deep drainage being deteriorated by proper surface manuring?—Not in such soils as the garden-ground on our commons, which has clay in it. It would have no effect in clayey soils, but in gravelly or sandy soils the water would run through, unless there was enough clay in it to arrest the ammonia.

Then all your experience corroborates Professor Way's experiments?—Most decidedly so.

What quantity of land do you farm?—Some 600 or 700 acres. I have a great quantity of hop-grounds, which require large quantities of manure.

There is a very cheap mode of distributing clay with sand over the surface by means of a jet. Have you had any means of considering how far that mode might be made available to form a surface for the discharge of water for drainage purposes?—I have not had the subject before called to my attention; but I cart clay upon my sandy soils.

Have you tried experiments on the effect of the filtration of manures through different soils?—Occasionally.

Have you tried experiments with regard to the detention of manure on the principle proposed by His Royal Highness Prince Albert, by means of filtration through ashes?—Yes, I have tried experiments which were on the same principle, some time since, only my filtrations were downwards, whereas His Royal Highness's proposal was that the liquid should be forced upwards through the ashes. My plan was to pump the liquid upon the ashes; that liquid consisting of the urine of some 300 or 400 sheep and other cattle, collected in tanks prepared for the purpose.

How long have you applied that plan?—That system has been in operation at my place for some three or four years.

Have you found the effect beneficial?—Extremely so.

Then, on the whole, you are satisfied with the result of this experiment?—I am satisfied that this is a capital means of distributing manure on the land, and I have found from experiment that one bushel of charcoal ashes will absorb the astonishing quantity of 9 or 10 gallons of this liquid manure.

What is the effect as regards the smell of the liquid after filtration?—

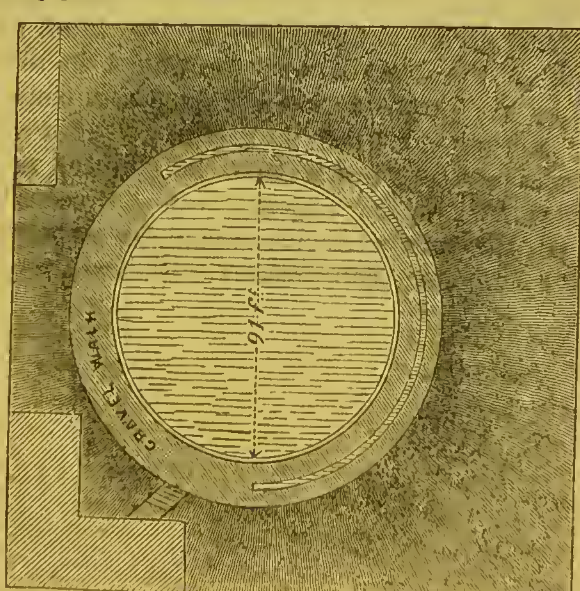
I have found that it then possesses very little smell at all, although before it was passed through the charcoal dust the odour was so offensive that you could scarcely bear it. All my experience on the subject tends to confirm the conclusions arrived at in the views laid down by Prince Albert. Mr. Paine.

What has been the effect of that kind of manure upon the crops?—I have always applied it in combination with other manures, and therefore I cannot state how much of the benefit I have derived is attributable to this portion of my manures. I esteem it very highly, and continue to make it in very large quantities; being perfectly satisfied that the excellence of my crops is greatly enhanced by this mixture.

LETTER from J. R. COULTHART, Esq.

"SIR, " *Croft House, Ashton-under-Lyne, Jan.* 10, 1850.

"In answer to your inquiries on behalf of the Metropolitan Commissioners, I beg to annex a Table expressly compiled by me for your information, which exhibits the positive quantity of water consumed in 4094 dwelling-houses in 168 hours, in May, 1847; and as the measurements connected with the experiment were taken by Mr. Henry Hibbert, Secretary to the Ashton-under-Lyne Waterworks Company, in expectation of his being sworn and cross-examined as to their accuracy before a Committee of the House of Commons in a matter involving the supply of the town of Manchester with water, great dependence may be placed on the correctness of the statements. Indeed, I am so satisfied of the accuracy of the observations and calculations made, that I doubt much if you will have a return from any other place more deserving of being relied upon. To enable you, however, to test the computations and also the soundness of the principles on which they are based, I subjoin to this letter a drawing of the filtration reservoir, together with the common arithmetical formula used in calculating the number of imperial gallons consumed in the 4094 dwelling-houses, as indicated by the lowering of the water in the circular filtration reservoir of 91 feet diameter, whilst the supply from the large upper reservoir was cut off. Mr. Coulthart.



Sketch of the Filtration Reservoir, Ashton-under-Lyne.

Mr. Coulthart.

"In answer to your inquiry, 'Whether, from further experience at Ashton-under-Lyne since writing my Report to the Health of Towns Commissioners, I would modify the information therein afforded,' I would simply say that additional experience has only more deeply confirmed the opinions which I then had as to the importance and economy of a continuous distribution of water for domestic purposes, by which tanks, ball-taps, and turncocks' wages are wholly saved, without anything existing in the unlimited-supply system to counterbalance these expenses, except, perhaps, that of laying down larger main-pipes. Indeed, daily experience is establishing in this part of England, and the annexed table corroborates the affirmative of the proposition, that a constant and unlimited supply is by far the cheapest method of supplying a given number of dwelling-houses with water; and that the system is not practically attended with that wasteful consumption of the precious fluid which the term 'unlimited' would seem to imply. When I wrote in 1843 my Report on the Sanitary Condition of Ashton-under-Lyne, I calculated that an unlimited supply of water involved a daily distribution after the rate of 55 gallons per house, or 10 gallons per head of the population supplied; but subsequent experience has satisfied me that that was an over-estimate of what the public voluntarily use, and that 40 gallons per house, or 7 gallons per head per day, is amply sufficient, on the average, to meet all requirements of a domestic nature.

"In closing this letter I give, as requested, some general information regarding the existing state of the Ashton-under-Lyne Waterworks as compared with their condition when I noticed them in 1843. You will thereby perceive that, though on the average we only charge 8*s.* 9*d.* per house per annum, yet the proprietors of the works realize a dividend of 7½ per cent. per annum on the capital expended in their construction (the highest rate of dividend that the Water Act permits to be divided amongst the shareholders, or a much higher could be paid from the profits), and that each of the 25*l.* water-shares are selling at nearly double their original cost. These facts lead me to doubt whether there are any towns in England or elsewhere, with an intermittent supply of water, that surpass Ashton-under-Lyne in the three grand requisites with promoters generally of undertakings of the kind, namely, in the lowness of the cost of the water to the consumers, in the height of the dividend realized by the proprietors, and in the augmented value of the capital originally invested in the undertaking. If my surmises be correct, a good argument might therefrom be deduced in favour of the constant and unlimited supply system, even on pecuniary grounds, which are, after all, the chief obstacles to sanitary improvement.

The comparative statement mentioned is as follows, viz.:—

Mr. Coulthart.

THE ASHTON-UNDER-LYNE WATERWORKS COMPANY.
(Established in 1835.)

	In 1843.	In 1850.
	£.	£.
Amount of capital invested	19,288	24,547
Expenses of management, including rates, taxes, and keeping the pipes in order	600	840
Net annual revenue, which was effected in 1845 by a reduction of the charges	2,400	2,600
Market price of shares (25*l.* paid up)	45	48
Average charge per house per annum	11*s.* 3*d.*	8*s.* 9*d.*
Entire number of dwelling-houses supplied from both reservoirs	4,500	5,700
Number of dwelling-houses in the town unsupplied	300	100
Entire quantity of water annually delivered to houses, factories, and railways, in millions of gallons	140	90
Average consumption of water per house per diem, in imperial gallons	39	39
Estimated length of cast-iron and lead pipes, in miles	11½	17
Number of fire-plugs in the town gratuitously supplied	150	200

"In addition to the fire-plugs the Water Company supply, free of charge, all churches, chapels, schoolhouses, town-halls, and other public places within the borough; also water for all purposes of general utility, such as for the monthly trials of the fire-engines, for the extinction of all accidental fires when they occur, for the watering of the streets in summer, &c. &c.

"I ought also to remark that the 140 millions of gallons, mentioned in the above statement as having been delivered by the Company in 1843, included the supply of water to sundry cotton-factories, for condensing purposes; many of which ceased to be supplied from the Ashton-under-Lyne Waterworks in 1846, a number of the factory-owners and occupiers having in the latter year established separate waterworks for themselves for these purposes.

"I have the honour to be, Sir,

"Your most obedient Servant,

"*Henry Austin, Esq.*" "JOHN ROSS COULTHART.

Mr. Coulthart.

TABLE showing the actual quantity of water consumed in one week in 4094 dwelling-houses in Ashton-under-Lyne, in the county of Lancaster, where a constant and unlimited supply has been in operation for a period of 14 years; distinguishing also the daily and nightly consumption of each house, and of each individual member thereof, as compiled by JOHN ROSS COULTHART, of Croft House, Ashton-under-Lyne, from measurements carefully taken of the depressions observed in a large circular filtration reservoir of 91 feet diameter, by Mr. HENRY HIBBERT, Secretary to the Ashton-under-Lyne Waterworks Company.

DATE.	Hours at which the Measurements were taken.	Distance of Water from top of Reservoir.		Depression of circular Filtration Reservoir of 91 feet diameter, whilst the supply of Water from the upper Reservoir was shut off.		Time.	Diminution of waste Goit during same time.		Total Quantity of Water absolutely delivered to 4094 Dwelling-houses.	Average Quantity consumed in each Dwelling-house.	Average Quantity consumed by each Individual supplied.*
1847.		Ft.	In.	Ft.	In.	Hours.	Ft.	In.	Gallons.	Gallons.	Gallons.
March 20 Saturday .	9 a.m.	4	$4\frac{1}{2}$	3	5	9	1	0	142,773	34·87	6·34
,, ,, Ditto .	6 p.m.	7	$9\frac{1}{2}$								
,, 21 Sunday .	9 a.m.	3	4	1	9	9	1	0	75,023	18·31	3·33
,, ,, Ditto .	6 p.m.	5	1								
,, 22 Monday .	9 a.m.	3	7	2	0	9	1	0	85,186	20·79	3·78
,, ,, Ditto .	6 p.m.	5	7								
,, 23 Tuesday .	9 a.m.	3	7	2	2	9	1	0	91,961	22·44	4·08
,, ,, Ditto .	6 p.m.	5	9								
,, 24 Wednesday	9 a.m.	3	$7\frac{1}{2}$	2	2	9	1	0	91,961	22·44	4·08
,, ,, Ditto .	6 p.m.	5	$9\frac{1}{2}$								
,, 25 Thursday .	9 a.m.	3	5	2	2	9	1	0	91,961	22·44	4·08
,, ,, Ditto .	6 p.m.	5	7								
,, 26 Friday .	9 a.m.	3	5	2	7	9	1	0	108,898	26·59	4·83
,, ,, Ditto .	6 p.m.	6	0								
,, 26 Friday .	6 p.m.	6	5	1	9	15	1	0	75,023	18·31	3·33
,, 27 Saturday .	9 a.m.	8	2								
,, ,, Ditto .	6 p.m.	4	6	1	8	15	1	0	71,626	17·49	3·18
,, 28 Sunday .	9 a.m.	6	2								
,, ,, Ditto .	6 p.m.	4	$2\frac{1}{2}$	1	$4\frac{1}{2}$	15	1	0	59,779	14·63	2·66
,, 29 Monday .	9 a.m.	5	7								
,, ,, Ditto .	6 p.m.	4	$1\frac{1}{2}$	1	3	15	1	0	54,698	13·31	2·42
,, 30 Tuesday .	9 a.m.	5	$4\frac{1}{2}$								
,, ,, Ditto .	6 p.m.	4	$1\frac{1}{2}$	1	$3\frac{1}{2}$	15	1	0	56,392	13·75	2·50
,, 31 Wednesday	9 a.m.	5	5								
,, ,, Ditto .	6 p.m.	4	0	1	4	15	1	0	58,086	14·30	2·60
April 1 Thursday .	9 a.m.	5	4								
,, ,, Ditto .	6 p.m.	4	8	1	3	15	1	0	54,698	13·31	2·42
,, 2 Friday .	9 a.m.	5	11								
Total per week . .				26	2	168	14	0	1118,065	272·98	49·63
Average per diem .				3	$8\frac{6}{7}$	24	2	0	159,723	38·99	7·09

* The population supplied with water is taken at 22,517, being after the ratio of $5\frac{1}{2}$ persons to each house, which was the average proportion given for Ashton-under-Lyne by the census returns, page 41.

Mr. Coulthart.

91 feet, being the diameter of Reservoir.
91
—
91
819
—
8281
7854 number for finding the area of the circle.
—
33124
41405
66248
57967
—
6503·8974 cubic feet in 1 foot of reservoir.
26·2 aggregate depression of reservoir.
—
1083
39018
13006
—
170161 cubic feet of water in 26′·2″ of reservoir.
6¼ number of gallons in a cubic foot of water.
—
42540
1020966
—
1063506 number of gallons in 26′·2″ of reservoir.
54411 number of gallons from waste goit.
Houses —
4094) 1117917 (272·82 gallons per house per week.
8188
—
29911
28658
—
12537
8188
—
3349·0
3239·2
—
109 80
81·88
—
27·92

Again:
Population 22517) 1117917 (49·64 gallons per head per week.
90068
—
217237
202653
—
14584·0
13510·2
—
1073·80
900·68
—
173·12

---

243 length of goit inside.
254·6 ,, outside.
—
2) 497·6
—
248·9 average length.
2·6 width of goit.
—
124·4½
497·6
—
621.10½ cubic feet of water.
2 emptied twice in 24 hours.
—
1243·9
6¼ gallons in a cubic foot.
—
310½
7462½
—
7773 total per day from goit.
7 days in a week.
—
54411 total gallons per week.

*** There is a trifling difference in the entire quantity of water delivered when computed in the aggregate as is done here, which arises from the remainders in the 14 similar calculations in the table, and the rejection of the above, or rather preceding, decimal of ·8974.

Mr. Lindley.

Wm. Lindley, Esq., C.E., examined.

1. What provision is made with the new system of works which you have laid down for the prevention of fires?—The mains are large, from 6 to 20 inches diameter, constantly charged at high pressure, being supplied from the one extremity by two Cornish engines, and at the other level from a high summit reservoir, kept constantly filled. Throughout the whole length of the pipeage are placed, at intervals of 40 yards, fire-plugs of three inches diameter in the clear.

2. How soon can a jet be applied?—In two minutes. The men who get paid by old custom for the use of their engines will come, although they are not wanted, but the power of eight engines may be anywhere applied as quickly as the hose can be screwed on, and introduced *inside* the house where the fire is.

3. Have there been fires in buildings in Hamburgh in the portion of the town rebuilt?—Yes, repeatedly. They have all, however, been put out at once. If they had had to wait the usual time for engines and water, say 20 minutes or half an hour, these might all have led to extensive conflagrations.

4. What has been the effect on insurance?—The effect of the rapid extinction of fires has brought to light to the citizens of Hamburgh the fact that the greater proportion of their fires are the work of incendiaries, for the sake of the insurance-money. A person is absent; smoke is seen to exude; the alarm of fire is given, and the door is forced open, the jet applied, and the fire extinguished immediately. Case after case has occurred where, upon the fire being extinguished, the arrangements for the spread of the fire are found and made manifest. Several of this class of incendiaries for the insurance-money are now in prison. The saving of money alone, by the prevention of fires, would be worth the whole expense of the like arrangement in London, where it is well known that similar practices prevail extensively.

5. Is the jet used at Hamburgh for watering the streets?—Yes; the charge has been 1*d*. per foot of frontage per annum.

M. Alexis Soyer examined.

M. Alexis Soyer.

You are known to the Commissioners from your writings on cookery; and you have doubtless had occasion to try the qualities of different waters for cooking and culinary purposes; you have probably used Thames water?—Yes, I have; when I first became cook to the Reform Club we occupied Gwydyr House, which was then supplied with Thames water.

What was your experience of it?—That it was very hard and inconvenient; it had sometimes a disagreeable taste; this, however, we found was occasioned by the cistern, which we remedied; it was, however, at all times very hard.

What was the effect of the hardness in cooking?—That we were in many processes obliged to use potass or soda for the water, to soften it.

What were the processes?—First, in boiling cabbage, greens, spinach, asparagus, hard water gives them a yellow tinge, especially in French

beans: hard water shrivels greens and peas, and will be more particularly noticed in French beans; the process of boiling is also longer. M. Alexis Soyer.

That requires more fuel?—Certainly.

What would be the difference in time?—With dry vegetables certainly one-fourth more.

How is it with potatoes?—I do not think it acts so much upon potatoes, but still it has an influence upon all sorts of vegetables. I do not see the same effects however upon roots generally as upon leaves generally; the effects are very powerful.

What do you find to be the effect of hard water upon the animal foods?—Upon salt beef the hard water is not so good, it does not open the pores of the meat so freely as soft water. On fresh meat it likewise has a prejudicial effect, but not equal to that on vegetables. It has the effect of making very white meat whiter than the soft water; upon all delicate things it has however a more marked effect—for example, in making beef-tea, chicken or veal broth, or upon lamb; and the more delicate a substance is, the greater is the influence of a hard water upon it. A hard water as it were compresses the pores, whilst a soft water dilates them and the succulent matter which they contain. It makes them more nutritious. The evil of hard water is more visible in small quantities, such as broth or beef-tea.

Then it will be more prejudicial or expensive in domestic cookery, which must be in small quantities?—Exactly so; in the larger operations, where there is much boiling, the boiling itself, and for a long time, reduces the hardness. In the small quantities requisite for invalids and delicate persons the disadvantages are the most experienced. When I used Thames water at Gwydyr House, I have had quantities boiled in order to soften it, and have then let it get cool and kept it ready for use for the smaller operations.

What is the effect of hard water upon bread?—I have not had practical experience in bread-making; but there is not the least doubt that soft water is of the greatest importance as making the best bread. This is exemplified in Paris, where the water is hard, and where that bread which is made in imitation of Gonness bread, though made with the same flour and by the same bakers, never equals that made at the place itself, where the water is soft. I am informed that part of the water at Glasgow is very soft, and that the Scotch bakers from thence, when they first come to London, cannot understand why the bread does not rise so well as in Glasgow, even though they make use of the same yeast and flour. It is well known that the addition of a small quantity of bi-carbonate of magnesia in the water renders bread lighter and whiter.

What is your experience in respect to tea?—The hard water is injurious in deteriorating the flavour; it also requires more tea to give an equal strength. There can be no doubt that the softer water is of very great importance; we have found it so with the water used at the Reform Club, which is Artesian well water.

In respect to coffee, what is your experience?—Hard water produces a similar effect, but not quite so powerful.

[The witness was requested to obtain more particular or closer proximate results as to the comparative value of Thames and the Artesian well water in making tea, taking into account flavour as well as strength of extract.]

M. Alexis Soyer.

Have you made the examination as to the comparative effect of waters of different qualities in the preparation of tea?—Yes, I have. In making the experiments, as time is of importance for the effect as well as for economy, I thought it proper to take an account of it. For culinary purposes I am confident that that water which boils the quickest is the best; and I conceived that this might be ascertained in respect to tea. I took samples of the common tea in use by the population, green tea and tea of a third class, and prepared them with equal quantities of water: I took, as the standard of soft water, distilled water, which I obtained from Apothecaries' Hall. The whole results were more striking than I had previously anticipated. The softest or distilled water had an extraordinary power in obtaining a quick extract; the result showed perhaps too high a power, for it draws out the woody flavour. Next to it was the Artesian well water, which is one-third less hard than the Thames water. I should indeed prefer that water to any other tried in these experiments: although the distilled water draws out the aromatic property of the tea more than the Reform Club water, it does not I think produce so good an extract. Each water gives its own shade, and had its own distinct extract. Finding the results so extraordinary, I solicited the assistance of two friends, Messrs. Hooper, the most eminent tea-tasters in London . the results were the same, and the following table gives the conclusions I came to:—(p. 233.)

Are you confident as to the difference in the time of boiling between hard and soft water?—My experiment was with pints of water, in the same size stewpan, with a gas lamp, so that the heat was manageable, and the same in both cases; and there was certainly a difference of full two minutes in favour of the boiling of the soft water; and the same result was given in several experiments.

From these experiments, and your extensive knowledge, will you state the general results as to the relative power of the hardest and the softest water in making tea?—I should say that whilst with the hard water three cups might be made, with the soft water about five might be made.

What extra expenditure of tea then would the use of the Thames water incur in making tea?—Nearly one-third.

That is on all the tea consumed in the metropolis?—Yes, I have no doubt of it.

Do you consider that the action of water in tea is a fair test and representative of its action on meat and vegetables in general, in all the delicate processes of cookery?—Yes, I do; and I have proved it in the following way. I have taken the solution of 16°, and compared it with the water from the well of the Reform Club. First, with vegetables, that is, carrots, turnips, and onions, cut into small pieces of about one inch long and an eighth of an inch square, such as are used in Jullienne soup, placed in two saucepans, with the same quantity of water, and on the same gas-stove: those cooked in the Reform water were quickly done, and the flavour of the vegetables in the water; whilst those cooked in the solution never became tender, nor did the flavour go into the water. Secondly, with potatoes: I cut a peeled potato into two, and boiled them at the same time in the above waters; the difference was easily distinguishable, that which was boiled in the hard water being harder, but at the same time whiter. Thirdly, in extracting the juice

M. Alexis Soyer.

Kinds of Water.	Time taken to boil.	Their rank in making of Tea.	REMARKS.
	Min.		
Distilled water from Apothecaries Hall	$5\frac{1}{2}$	2	
Covent-garden, an Artesian well* .	$8\frac{1}{2}$	5	* Impure as if it contained iron.
Reform Club, 360 ft. deep,† and Trafalgar-square . .	$6\frac{1}{2}$	1	† This well has been sunk ten years; the pipes are the same as at first laid down, but they are all blistered. This makes tea one-third more than any other water.
Camden Town, sunk 200 feet in the chalk‡ . . .	8		‡ This is the well sunk by the North-Western Railway Company for the supply of their locomotives. I moved the machinery for manufacturing the nectar into Whittlebury-street, close to Euston-square Station, in order to receive the advantages of this water, and paid a large sum per annum to the Company to obtain it; but I find that the water, in passing through the iron pipes from Camden Town to the station, becomes so impregnated with iron as to cause it to be considerably altered in its nature. This fact may be seen by the deposit of iron it leaves at the urinals in the station; it likewise makes deep grooves in the pipes, as if planed out with a machine.
New River, from a cistern in Billiter-street, City . .	8	3	
Wellclose-square, a spring. . . .	10		
Camberwell, a sunk well, 60 feet deep§	10		
Thames, from Hungerford, 2 hours after high water .	$9\frac{1}{2}$	4	
Standard solutions of lime-water, reckoned according to Clark's scale of hardness :—			§ Camberwell is considered the hardest water in the vicinity of London.
2°‖	7	6	‖ Of the three No. 2 is by far the best.
8°	$7\frac{1}{2}$	7	
16°¶	$8\frac{1}{2}$	8	¶ Very impure, and boils with a scum upon it.

or gravy from meat: the soft water does so quickly and well, but the hard water, instead of opening the meat, seems to draw it closer together, and to solidify the gluten, and I believe that the true flavour of the meat cannot be extracted by hard water. In boiling of salt meat less salt is extracted when boiled in hard water, and at the same time the meat is not so tender as when boiled in soft water. Soft water evaporates one-third faster than hard water. I should, in every way, give the preference to soft water, but, at the same time, if very tender meat is required to boil very white, hard water should be used.

You were requested to try as completely as you could some soft water from Farnham and ascertain its value for culinary purposes, have you done so?—Yes, I have compared it on trial with between 40 and 50 specimens of different waters; some I had from Ireland, some from Scotland, and I found it the best of the whole, and very nearly of the quality of distilled water. In cooking some vegetables, however, I found the artesian well water somewhat better than the Farnham water.

M. Alexis Soyer.

The water of the artesian well is alkaline, and that is a quality peculiarly favourable to solubility?—Yes.

As a soft water, do you find that the Farnham water has the general power which you ascribe to the softest waters—generally as compared with the river Thames water?—Yes; for, as compared with the Thames water, its power of extraction would then be as about six to four. But the flavour of the tea produced by softer water would be greatly superior.

Was the proportionate rate of boiling the same as that which you ascribe to other soft waters?—Yes; very decidedly; it boils, in the quantities I used, much quicker than the hard water.

EXTRACT from a LETTER of JOHN BULLAR, Esq.

Temple, January 24, 1850.

Mr. Bullar.

I COMPLY, as well as I can, with your request that I would give you the data on which I arrived at the conclusion that "the washing-bills of London amount to 5,000,000*l.* a-year;" premising that by "washing-bills" I mean the total cost of washing.

In the year 1844, when "The Committee for promoting the establishment of Baths and Washhouses for the Labouring Classes" was formed, it was deemed advisable to ascertain, as accurately as possible, the actual wasbing expenses of labouring men and their families whose washing was done at home. Inquiries were, therefore, made of several hundred families of labouring men, and it was found that, taking the wife's labour as worth 5*s.* a-week, the total cost of washing at home, for a man and wife and four children, averaged very closely on 2*s.* 6*d.* a-week = 5*d.* a-head. The cost of coals, soda, soap, starch, blue, and sometimes water, was rather less than one-third of the amount. The time occupied was rarely less than two days, and more often extended into a third day, so that the value of the labour was rather more than two-thirds of the amount.

I may mention here that the average time occupied by a woman in washing and drying her family's clothes at the model establishment of Baths and Washhouses, Goulston-square, Whitechapel, and the St. Martin-in-the-Fields Laundries, may be taken at about two hours and a-half, and the payment for that time, which covers the expense of coals and water, is 3*d.*; so that already (for such establishments are but in their infancy, and are capable of considerable improvements) the 2*s.* 6*d.* a-week may be considered as being reduced at least one-half to those who avail themselves of the washhouses.

In the course of the two succeeding years I made inquiries, as opportunities offered, of the cost of washing to single men among the labouring classes, whose washing expenditure might be expected to be on a very low scale, such as hod-men and street-sweepers; and I found that the lowest average weekly cost of washing to such of them as could reckon it, was 4½*d.* a-head.

I found it very difficult to ascertain the cost of washing to very small tradesmen; but I came to the conclusion, that it could not be safely estimated at much more than 6*d.* a-head a-week. Many of them maintain a position of solvency only by the narrowest economy, and it is

probable, not only that their expenditure for personal cleanliness exceeds but little, if at all, that of mere labourers, but that they have a direct personal interest in the establishment of parochial washhouses. The Rev. Sir H. R. Dukinfield, who was intimately acquainted with the condition of his (late) parish, St. Martin's, was so strongly impressed with this being the case, that he suggested the first-class washing-places for them which have been provided in that parish. Mr. Bullar.

It may, perhaps, be safe to reckon the weekly washing expenses of the poorer half of the inhabitants of the metropolis as not exceeding 6*d.* a-head; but the expenditure for washing rapidly increases as the inquiry ascends into what are called "the middle classes." Among them, various sums, from 9*d.* to 1*s.* 6*d.* a-week a-head, are allowed to maid-servants for their washing, and besides that allowance, they very commonly wash at home small articles, such as caps, collars, &c., for themselves, and not, I apprehend, with any very strict regard to economy of fuel, soap, &c. The weekly allowance for washing to men-servants range, I believe, from 1*s.* to 2*s.* 6*d.* a-week, and a little washing at home is not unfrequently done for them.

It is, perhaps, safe to consider the washing expenses of the families in which those servants are employed as at double the rate of that of the servants, and, therefore, as ranging from 1*s.* 6*d.* to 5*s.* a-week a-head. In many of the wealthier families it is much higher. I have found the weekly washing-bills of young men living in chambers to range from 3*s.* 6*d.* to upwards of 10*s.* a-head.

You will easily imagine the difficulty of ascertaining with any exactness the washing expenditure of private families, and my consequent necessity of making this rough estimate. The conclusion at which I arrived was that, taking the whole population, the washing bills of London were nearly 1*s.* a-week a-head, or 5,000,000*l.* a-year. An examination of your objection that "that was half the rated rental of the metropolis," has tended to confirm me in that conclusion.

The rated rental of a house occupied by a labouring family, whose weekly washing expense is 2*s.* 6*d.*, is probably rarely equal to 5*s.* a-week. Where such a family occupy a part of a house, the proportion of that rental attributable to their rooms, or their single room, is probably decidedly less than 5*s.* a-week, except in peculiar cases. It is, therefore, not improbable that the yearly washing expenses of the poorer half of the inhabitants of London are quite equal to one-half of the rated rental of their dwellings.

The washing expenses of a middle-class family, inhabiting a house rented at 120*l.* a-year, and rated (high) at 100*l.* a-year, consisting of husband and wife, three children, and three servants, may be taken at not less than 20*s.* a-week, or more than half the rated rental; and from all that I have been able to learn, the proportion which washing expenses bear to rent is much greater in those families whose income is large enough to free them from the necessity of studying economy in matters of ordinary domestic expenditure. It is said that the average yearly value of the houses in London assessed under the income tax is 40*l.*; and that the average number of persons to every inhabited house in London is 7·4. At 1*s.* a-week a-head the washing-bills of the persons inhabiting each of those houses would be within a very small fraction of 20*l.* a-year.

Mr. Bullar.

Whether you take 1*s*. a-week a-head for all the inhabitants of the metropolis, or one-half of the rated rental of its houses, the washing-bills come, in round numbers, to 5,000,000*l*. a-year. Of course I give this as but a rough estimate, and many exceptions may easily be taken to it; but I feel pretty confident that it is not very far from the truth. It is some years since I worked it out, and I did so to a considerable extent from data which I have not preserved in writing; but it is, perhaps, quite as accurate as an estimate of the population of England in the reign of George II., of the total amount lost in a year in England by bad debts, of the numbers who die yearly from preventible diseases, or any other of the rough estimates which are used for statistical purposes, as not being too grossly inaccurate to be so used.

Quantity of Water required for Baths in the Metropolis.

Extract from a Communication by John Bullar, Esq.

My dear Sir, *Putney, April* 16, 1850.

The existing baths and wash-houses in London are (in the order of their opening for work),—1. Those in Glasshouse-yard, near the London Docks; 2. Those in George-street, Euston-square; 3. The model establishment, Goulston-square, Whitechapel; 4. The St. Martin-in-the-fields parochial establishment; and 5. The St. Marylebone parochial establishment. Baths and wash-houses are in course of erection or determined on, for; 6. The parishes of St. Margaret and St. John, Westminster; 7. St. James's, Piccadilly; 8. St. Giles and St. George, Bloomsbury; and 9. Greenwich. I do not include such parishes as Lambeth, where the adoption of the Act has not yet been followed up by the appointment of Commissioners to carry it into execution.

Leaving out Greenwich, as being beyond the limits of mere metropolitan water supply, and Glasshouse-yard, as being a small establishment supported as a charity for the very poor, and not reckoning plunging baths, there will probably be about 600 baths in the seven other establishments.

The greatest amount of custom that has yet been known was at the St. Martin-in-the-fields establishment, where upwards of 2000 persons bathed in one day last summer. This was at the rate of about 30 bathers to every bath. At this rate, there might be 18,000 bathers in a day in the seven establishments; and I doubt whether 30 bathers to every bath should not be considered the highest daily number that, on the average of seven or more establishments, could be reckoned on. Assuming the baths to be open from 6 A.M. till 11 P.M., with two sets of bath attendants, there might, with a regular influx of bathers, and the greatest economy of trouble given and attention paid, be as many as 50 bathers to every bath; but there are some hours in every day when there is but little custom, and a very large amount of custom requires the employment of extra attendants, who do not get through their work as expeditiously as the constant attendants.

The actual amount of water used in a bath by every bather is from 40 to 45 gallons, but an allowance has to be made for some waste, and for what is used in a steam-engine, and for cleansing the building. In

Mr. Bullar.

estimating for a supply, it would not be safe to reckon on having at command less than 50 gallons for every bather. Nor would it be safe to be content with having a less quantity of water at command on every day than the largest quantity that might be required on any one day, according to the season. The greatest supply is wanted in the hottest weather in summer; and if the proper amount can be had then, there will be no doubt about having enough during the rest of the year.

At 50 gallons for every bather, there ought to be the means of having, in the height of summer, a supply of not less than 900,000 gallons (about 150,000 cubic feet) of water every day.

Assuming that there will be in every wash-house as many pairs of tubs as there will be baths in the same establishment; or 600 pairs of tubs in the seven establishments; and that, on the average of the year, the wash-houses are in use 10 hours a day, the daily supply of water at command ought not to be less than 36,000 gallons (about 6,000 cubic feet) more. This is on the estimate that every washer will take two hours and a half at her work, and use 15 gallons of water.

For the sake of a margin for safety, the daily supply which the seven establishments ought to have should be about 1,000,000 gallons.

I have thus answered, as well as I can, your first question.

Your second question is not so easy to answer without appearing to run into exaggeration, and therefore I may as well premise that, when "the Committee for promoting the establishment of Baths and Wash-houses for the labouring classes" began their labours in the year 1844, the prediction that in six years there would be as many establishments of public baths and wash-houses in London, and about 30 more in other towns; and that the bathers in warm baths, chiefly of the labouring classes, in London alone, would exceed 400,000 in a year; and that not far short of a quarter of a million of pounds sterling would be expended for providing those establishments, would have been received, very generally, as utterly incredible. We may speak rather more confidently now; but still it will be advisable to imitate the prudence of Stephenson who, for fear that his evidence should be altogether discredited, did not dare to suggest to the Committee of the House of Commons on the Liverpool and Manchester Railway, that his locomotives would do more than 10 miles an hour.

I will therefore assume that the day may come when one-fourth of the inhabitants of London may like to have warm baths occasionally, and that each of them may be content with one bath a month. Taking that one-fourth at 500,000, the yearly number of baths taken would be six millions. At present, the bathing during the four warmest months is more than equal to that during the rest of the year, and at that rate, at least three million baths would be taken in twelve weeks. In round numbers, and assuming the average daily number of bathers in every bath to be 15, or one-half of the highest number, about 2,400 baths would be required for about 36,000 daily bathers, but the water supply at command ought to be sufficient (as shown above) for the highest daily number that could be expected, 72,000; and therefore the total daily quantity of water ought not to be less than 3,600,000 gallons (about 600,000 cubic feet) in addition to the quantity now required. 2,400 pairs of wash-tubs, at 60 gallons of water for each, would require 144,000 gallons (about 24,000 cubic feet) more in the daily supply.

Mr. Bullar.

Some deduction from the quantity of water required for baths has to be made on account of little children, several of whom bathe together; but, on the other hand, some addition has to be made for plunging-baths; and the two items may perhaps balance each other. We know not yet what may be done in bathing children. It would be of great good that the children in parochial and other schools should have warm baths once a week; and this might be effected without any great expense. The Committee have had under consideration a contract to bathe all the children of a large school, weekly, at 2*l.* a thousand; bathing two together in the same warm bath, and giving each a clean towel; but I doubt whether there would not be a small loss from this. 2*l.* 10*s.* a thousand would probably leave a small profit.

In answer to your third question, I should say that 50 gallons would probably be the largest quantity of water used for a single bath, and 40 gallons the smallest, reckoning waste. The Act allows four children under eight years old to bathe together, and they would not require more than 50 gallons between them.

It is but right that I should mention that the East London Water Works Company are very liberal in their charges for the water supplied to the model establishment; making a low estimate of the quantity supplied, and charging for it only half their usual rate. My estimates are, of course, higher than theirs would be; but you only ask for "proximate information," and I cannot profess to give you other than round numbers.

In multiplying the daily quantities to ascertain the year's supply, an allowance must be made for Sundays. With the sanction of the present Archbishop of Canterbury and the Bishop of London, the baths are kept open from six o'clock to half-past eight o'clock, A.M. on Sundays, so as to afford an opportunity of bathing to those labouring men whose work lasts till late on Saturday night, or who cannot be accommodated then. The pressure on a Saturday night is sometimes so great that hundreds are obliged to go away without being able to have a bath.

I have not the means of well answering your fourth question, as to the quantity of water required for the yearly washing of the clothes of every individual It has been estimated that every woman who resorts to the wash-houses once a week washes on the average the clothes of about eight persons. This would give nearly two gallons a-week, or about 100 gallons a-year, for every person. The articles washed by her are for those whose clothes are but few; persons whose weekly washing expenditure may be about 5*d.* a-head. Taking the average weekly washing expense for the population at 1*s.* a head (according to my letter to you of January 24), and the expenditure of water for washing to be in proportion to the money expenditure for it; we should thus have about 240 gallons a-year for every person, or (reckoning the population within the limits of metropolitan water supply at two millions) an aggregate of 480,000,000 gallons (about 80,000,000 cubic feet) a-year for the metropolis. But I doubt whether this would not be much too low an estimate.

Those who now resort to the wash-houses have learned, of necessity, great economy in the use of water and soap, and it is probable that, from habit, as well as to save in soap, they use at the wash-houses little more water than they can help; but it is probable that washers who have water at command and turn into lather the soap for which

others pay (including a considerable number of those who do the work of washing at home) are much more liberal in their use of water. Wherever the supply of water is unstinted, and the disposal of it when dirty does not give much trouble, a very far larger quantity of it is likely to be used in rinsing the articles washed than can be the case among the very poor who often have to carry to and fro all the water that they need. I am, therefore, not inclined to disbelieve that the estimate which you mention of 400 gallons a-head yearly may be nearer the fact than that of 240 gallons, making the aggregate 800,000,000 gallons, (about 130,000,000 cubic feet) a year. Mr. Bullar.

William Hawes, Esq., examined.

1. Will you state to the Commissioners what your information is as to the probable quantity of soap consumed in the Metropolis, or any proximate estimate you may have formed, and your data for the same, as to the consumption of soap by persons of the labouring classes of society?—Some years since (1844) I estimated the consumption of soap by the different classes of society with great care. The basis of the calculation was the quantity of soap charged with duty by the Excise. Careful inquiry proved that the quantity used was much greater than that indicated by the Excise returns; but reducing the results obtained by inquiry in one uniform proportion, the quantity used by the labouring classes earning from 10*s.* to 30*s.* per week is 10 lbs. each per annum, including every member of his family. Dividing the population of the Metropolis into 3 classes, the wealthy, the shopkeepers and tradesmen, labourers and the poor, and allowing 15 lbs., 10 lbs., and 4 lbs. to each respectively, the consumption of the Metropolis will be nearly 200 tons per week. Mr. Hawes.

2. Can you estimate the probable expenditure, from any data you have, proximately or otherwise, of the population in washing?—The quantity of soap used annually in England for the purposes of cleanliness is about 55,000 or possibly 60,000 tons, but this is exclusive of the quantity supplied by illicit trade. The value of this soap, at 45*l.* per ton, is 2,475,000*l.*

3. Can you estimate the expense of washing with hard water as compared with soft?—Since the manufacture of crystals of soda at a very low price, and its almost universal use in washing, the waste of soap from washing in hard water has been very trifling. The quantity of soda used to soften water, as it is called, is a source of expense, but of a trifling amount.

4. Are you not a partner in a brewery situated near the banks of the Thames?—Yes.

5. Do you use Thames water in brewing? If not, why not?—No. I cannot say why not. Before a deep well was sunk, the brewery was supplied by the Chelsea water-works, but the supply was so irregular and the charge so high, that a well was sunk on the premises; but why this was done in preference to laying pipes to the river, I cannot say. The lower temperature of the deep well water was probably one reason, and the trouble which a supply of pure water would save in

Mr. Hawes, cleaning tanks, &c., no doubt another. But I have not heard any fault of the quality of the water supplied by the Water Company assigned as a reason for discontinuing its use.

6. What is the degree of hardness of the water you use?—The water is very soft, containing only a little carbonate of lime and soda.

7. What is the expense you incur in obtaining the separate supply of soft water for your own use?—It is difficult to say exactly. The steam-engine is always pumping. The quantity raised is about 80 gallons per minute raised to a height of 120 or 130 feet.

8. Are you aware whether there are other brewers in London who use the Thames water? If they do not, why do they not use it?—I cannot answer this question.

9. Will you state what is the difference in the solvent power of water of 2 and of 4 degrees of hardness in the extraction of the saccharine matter from a given quantity, say, a quarter of malt?—I do not know what is meant by 2 and 4 degrees of hardness; although I am not replying from actual knowledge, I should not think any water used by brewers in or near London contains sufficient earthy matter to affect its extractive power. Earthy or metallic salts would affect the fermentation of the wort no doubt.

10. As an active member of the Committee for the erection of Baths and Wash-houses, you have probably examined the expense of washing on a scale:—Will you state what it is, and any contrast which it may be in your power to give of the actual expense of separate washing by the poor?—I have no experience of the cost of washing on a large scale. The principle of the establishment for Baths and Laundries for the poor is to provide separate places for each washer. It appears to me, from the nature and condition of the linen of the poor, that it is quite impossible to wash it in bulk.

11. Have you any knowledge of the relative value of hard and soft water for making tea for culinary purposes?—No: but hard water generally becomes soft by boiling. The decreased specific gravity of the water when heated, as well as the mechanical effect of steam bubbling through it when boiling, causes many earthy salts to be precipitated. See the incrustation of earthy matter in kettles, boilers, &c.

Charles Gatliff, Esq., examined.

Mr. Gatliff, I believe you are the Secretary to the Society for Improving the Dwellings of the Labouring Classes?—I am Secretary to the Metropolitan Association for Improving the Dwellings of the Industrious Classes.

Will you state what was the expense, in the several blocks of buildings belonging to that Society, for laying on the water?—The expense of laying on the water, including cisterns, ball-cocks, extra pipes, &c., was—

	£.	s.	d.
In the buildings of the Association in the Old Pancras-road	517	0	0
In the dwelling for single men in Albert-street, Buxton-street, Spitalfields . . .	92	0	0
Dwellings for families, in Albert-street, aforesaid .	240	15	0
	£849	15	0

How much of this was due to the cisterns?—488*l*. 10*s*. Mr. Gatliff.

How much would it have been in the absence of cisterns?—In the absence of cisterns alone it would have been 361*l*. 5*s*. In the absence of cisterns, ball-cocks, extra pipes, &c., it would have been 92*l*. 15*s*., unless other arrangements were necessary, upon which I should not presume to give an opinion. Our contractors consider stronger rising mains would be necessary.

Did you make application to any of the water companies to give you a constant supply for the buildings?—Yes; I applied to the New River Company, and also to the East London Waterworks Company, through the Surveyor of the latter.

How was the application received by the Board of Directors?—The Directors of the New River Company stated that it could not be furnished, and doubted its practicability. The Surveyor of the East London Waterworks Company stated they did not furnish a constant supply from the main; that it would be always on to the ground-floor cisterns, and that the other cisterns would be filled every night.

How much will the cisterns add to the rent, including in your estimate of the rent not only the original outlay, but calculating for wear and tear and dilapidation?—The cisterns, ball-cocks, extra pipes, and wear and tear of them will amount to 2*d*. per week for each set of rooms, as near as I can calculate, the rents of which vary from 3*s*. 6*d*. to 6*s*. 6*d*. per week.

Is the water delivered unfiltered?—I should term it so, though I have understood both companies have filtering-beds.

Do the tenants filter it themselves?—I do not think they do.

Have you considered the means of filtration for these houses?—I did with regard to the dwelling-house for single men, in Albert-street, Spitalfields. I have had Mauras's filtering-machine under consideration, and hope I shall yet succeed in bringing it into operation there.

What are the obstacles to the introduction of filters?—The expense to the class of tenants sought to be benefited by this Association.

What would be the expense if you were to provide filters, and charge them to the tenants in the rent?—I should think not more than 1*d*. a week.

In respect to the supply of water, have you found the soil-pans produce as little trouble as, or even less than, common bogs or cesspools?—On two years' experience only of 110 soil-pans, in the Metropolitan Buildings, Old Pancras-road, I should say they were preferable to common bogs or cesspools, both on account of trouble, and also the facility of giving one to each family, which I think is attended with very good effects on the morals and decencies of the tenants. I have only as yet had a few weeks' experience in the dwelling for single men in Spitalfields. The houses for families there are not yet finished.

Capt. Huish.

LETTER from MARK HUISH, Esq.

London and North Western Railway,
General Manager's Office,
Euston Station, January 9, 1850.

SIR,

IN reply to your letter of the 3rd instant, written by direction of the Metropolitan Sanitary Commissioners, I beg to send you the following particulars of the supply of water for the use of the Railway Company.

This supply is derived from two sources; first, that required for the locomotive engines; and, secondly, that for the purposes of the offices at Euston Station, for washing carriages, the supply of the Euston and Victoria Hotels, and for the tenants of the Company's houses adjoining the Camden and Euston Stations.

First, the supply of water for locomotive engines.

This is derived from the Regent's Canal, whence the water is pumped into tanks provided for its reception. The reason for our continuing the use of the canal water will be seen in my further remarks.

Second, the supply of water for Euston Station.

This is derived from an artesian well, sunk at Camden Station two years ago. This well passes through the London clay into the chalk. The well is 9 feet 6 inches in diameter for a depth of 180 feet, where it terminates upon a cast-iron plate, in the centre of which is an aperture 12 inches in diameter, through which a bore-hole is carried down a further depth of 220 feet, the last 166 of which is in the chalk; the total depth of the well and boring is 400 feet. The water used to stand at a level of 144 feet from the surface of the ground, but it is now about 6 feet lower; whether this arises from the exhaustion of the springs, or from the bore-hole having become partially choked, is a matter which can be determined by clearing out the hole with the boring tackle.

Our engineer, Mr. Dockray, informs me that the water has been analysed, and that it contains as follows:—

	Solid Matter per Imperial Gallon. Grains.
Sulphate of soda	13·00
Carbonate of soda	17·60
Muriate of soda	11·10
Carbonaceous matter and traces of silica	2·30
	44·00

For household purposes this water is exceedingly good, and is in high repute with the Company's tenants.

It was originally the intention of the Company in sinking the well to derive a supply for the locomotive engines at a lower cost than they could get it from the Regent's Canal Company. It was supposed that the water would be suitable for the locomotive engines, because that obtained from the chalk at Tring and Watford was all that could be desired. On trial, however, much to our surprise, the water from the Camden well, although derived from the chalk, was found to prime so

violently as to be quite useless for locomotive purposes, without the admixture of some chemical ingredient to neutralise its alkaline properties. We were, therefore, obliged to return to the canal for the supply for this purpose. Capt. Huish.

The analysis of the waters from Tring and Watford shows that they contain only about one-half of the solid matter that the water from Camden well does, and that this matter is lime, and not soda.

The consumption of water from the well at Camden Station is 121,750 gallons per diem.

Should there be any further information which you conceive would be interesting to the Commissioners, I shall be happy to supply it; and our resident engineer (Mr. Dockray), who is a highly intelligent officer, would probably be able to give valuable information, certainly, far more than I can, should the Commissioners think it desirable to examine him.

In conclusion, I may add that a very accurate account of the Camden well and of several others may be found in "Weale's Rudimentary Treatise on Well-digging and Boring."

I am, Sir,

Your obedient servant,

MARK HUISH.

To the Secretary of the
Metropolitan Sanitary Commission,
Gwydyr House, Whitehall.

William Millard, Highgate, examined.

You are head plumber in the employ of Mr. Worley of Highgate?—I am. Mr. Millard.

How long have you been in his service?—Upwards of four years.

Mr. Worley has considerable business in the plumbing trade in Highgate and the neighbourhood, has he not?—Yes; he does the principal business here. He has carried on the trade here all his life, and his father before him; but he has lately had a paralytic seizure, and is now unable to follow his business.

Do you attend to the out-door work?—I attend solely to the plumbing work; I have nothing whatever to do with the painting.

Before you came to Highgate, had you much experience in the plumbing trade elsewhere?—Yes, in London; where I served my apprenticeship to Mr. Hatton, who was a very experienced plumber.

Have you had in the course of your business, many opportunities of observing the action of water on lead?—I have had constant opportunities of observing the action of water on leaden cisterns and pipes.

The water in Highgate is particularly hard, is it not?—I never knew a place where it was harder; it is harder in some parts of the village than in others, but altogether it is harder here than anywhere else in the neighbourhood.

You speak of the deep well-water?—Yes.

The New River Company supplies some of the houses with water?—Yes, it has done so for about five or six years.

What is the quality of the New River Company's water, as to hardness?—That also is hard; but not nearly so hard as the well-water.

Mr. Millard.

What is your observation of the diffeent action of hard and soft water on leaden cisterns?—The hard water eats the cistern away; the soft water, that is rain water, does not sensibly touch it at all. The hard water of Highgate will, in a few years, eat the bottom of a leaden cistern entirely away, so that it will be useless.

In how many years?—In about three or four years.

Does not a leaden cistern usually last longer than that in Highgate? No; it eats holes in the bottom, particulaly at the places where there is solder, giving it a honeycomb appearance. This is so much the case, that it is a common custom here for the people to have their cisterns painted.

Is that a protection?—Yes, if the paint is allowed time to get thoroughly dry before the water is let into the cistern, the water does not act upon dry lead, and the cisterns will then last for years.

What would be the appearance of a leaden cistern holding rain-water, at the end of four years?—It might be black and dirty from the settlement of filth from the roof and so on, but when it came to be scoured out and cleaned, the lead itself would be as good as new.

Have you seen many examples of this?—Yes; it is the general experience, and there is in this house an example of it. There are in this house two cisterns, one for hard and the other for soft water. The bottom of the hard water cistern is full of holes, though not quite through; but the rain water cistern is no worse for use; when I cleaned it out a short time ago, it seemed to me as good as new.

Have you observed the action of the water supplied by the New River Company on cisterns?—I have cleansed many out, and have observed that the corrosion is not half as great as in the case of the harder water. The cisterns which contain the New River Company's water, last twice as long as the well-water cisterns.

There are then in Highgate three kinds of water—a very hard water, a water of moderate hardness, and a soft or rain water—and you have had opportunities of observing the action of each kind of water on leaden cisterns and pipes?—I have, and from all my experience, I think the effect of hard water upon lead is far greater than the effect of soft water. I have always found the harder the water the quicker it eats the lead away.

Mr. William Melhuish, Plumber, &c., of 9, Bedford-street, Bedford-row, examined.

Mr. Melhuish.

You have resided, I believe, some years in London?—I have for many years, and before that I lived in Bath and Bristol.

Have you not, in the course of your experience, found that people have of late years paid much more attention to the qualities of the water they use than they used to do?—Yes, decidedly so.

We have been informed that lead cisterns in and about London are found much worn at the bottom and sides; can you speak to this from your experience?—I have found them so worn at the bottom but not at the sides, except in some cases at Hampstead, where the water preys upon the sides and partly destroys it. I have found carbuncles stuck on it as large as my thumb.

That was hard water, I suppose?—Yes? and the water delivered at

Mr. Melhuish.

Kentish Town is ten times worse. The Hampstead ponds, from which I think the water comes, are full of animalculæ, and especially of those with long bodies and large heads. There are, indeed, all sorts of insects in the water. I had to live in Kentish Town for two years for the sake of the health of my daughter, and I found the water there so bad that I made a contrivance by which I always procured distilled water for my use. I had a leaden vessel prepared, into which water was conveyed from the cistern, and from which a pipe conveyed the water to the boiler. From the boiler another pipe carried the steam into an outer case which surrounded the cold water vessel, and which formed, as it is termed, a double jacket to that vessel. The steam was thus condensed, and the distilled water was received into jars from a pipe communicating with the outer case of the cold water vessel. I had thus always clear pure water to drink and to use for other purposes. Comparing them, the distilled water looked like a white handkerchief, while the other was like a brown towel.

What residue was there left in the still?—When I cut it open to ascertain the effect of the water upon the lead, I found all quite clean as when first put up. I continued thus to distil the water until I left Kentish Town, owing to my daughter having recovered her health. I could always tell the difference when other than this distilled water was used for making our tea. When I was away once for a few days the still was unused, and I immediately distinguished the difference.

Did you notice how far the tea went, using soft water, compared with hard?—No, I did not; but I know that I got better tea with the distilled water. And it was so soft that you could wash your hands in it almost without soap; and the difference the use of the two waters made in the appearance of laces and caps was astonishing.

Then you thought it quite worth while to distil the water?—Yes, I continued to do so till I left the house.

Have you observed that all Thames water acts upon lead cisterns?—Yes; but in some old cisterns of 200 years of age, and which are made of very thick lead, the water has only eaten half through them, while in modern cisterns the water has eaten quite through the lead.

Is all this eating from within, or is it the action of rust, or the decay of the cistern from the outside?—No, it is the action of the water within upon the bottom.

In what time have you had cisterns thus destroyed?—In one instance, where I had as usual used lead 8 lbs. to the foot, it was, to my great surprise, eaten through in three years. I had to put a new cement bottom. That was Kentish Town water.

Have you had similar results with the Thames water?—Yes.

And with the New River water?—I have had a cistern 16 years in wear, and there are now only a few spots on the surface of the lead. That is New River water. And I conclude from this and other circumstances, that not only some water acts more on lead than other water, but that water acts more on some kinds of lead than on others; the difference resulting from the lead being brought from different parts of the country. I conceive as much difference arises from the lead-mines it comes from as from the water which is used.

Will you state an instance in which you have found that the New River water has acted upon the lead?—There was one lately, but the

Mr. Melhuish.

cistern had been in use many years. I certainly think it preys less on the lead than the Thames water. At Bromley, too, I have found the water eat through thick lead pipes in two years. That is the quickest action of water on lead I know of.

In what parts of the metropolis have you had cisterns to repair on account of the bottoms giving?—In Wandsworth, in the Southwark and Vauxhall district, and in the West Middlesex district.

Did you find much difference in the action of the water on lead in the Grand Junction district, where the water is filtered, and in the West Middlesex, where the water is not filtered?—No; and I have found the incrustation takes place quite as much from filtered New River water as from common unfiltered water.

Supposing you had a long range of buildings, and had to put cisterns to them, and used either filtered or unfiltered water, how much per centage ought fairly to be put down for dilapidations; or supposing you wanted to form a fund to cover any damage or repairs, what period do you think it would be safe to calculate the cisterns would require renewing?—I should say they would want new bottoms in 30 years, supposing the 8 lb. lead and New River unfiltered water to be used.

In the New River and other districts have you found any trace of wear in the house-service pipes when they have been taken up?—No. I have never found anything of that kind. The water does not seem to act on the pipes that merely supply it, but on the bottom of the cisterns where the water remains.

What water is that you spoke of at Bromley?—I have no doubt it was impregnated with lead; that kind of water eats away lead quicker than any other.

Did your distilled water act on the interior of the pipes?—No.

Are you aware that at the Bishop's Palace at Farnham, where they have water of not more than one degree of hardness, they have never been inconvenienced from the action of the water upon the lead?—No, I am not; but during my seven years apprenticeship in Bath, I never remember any inconvenience of the kind from the soft water which they have there, and which comes from the freestone.

You say that Kentish Town water is impure?—I think it the most impure, and the New River by far the best of the London waters.

Are there many places in London where you have put cisterns for rain water?—Yes; but rain water never acts upon the lead, and I never knew a rain water cistern that was decayed.

Then, from all your own practical experience, first, of the effects of soft water at Bath, and then of hard water in London, you would not be afraid of a supply of soft water to the metropolis?—Certainly not. I have never found any action from the water either in soft-water cisterns or pipes.

If you could get water as nearly to distilled water in purity as possible, would you not esteem it a blessing to the population?—I do not know how the apparent fact would operate that the purer the water the more it preys upon the lead.

But does not your experience, both as to rain water and the Bath water, show that pure water does not act upon the lead at all?—Certainly, I have always found that they do not.

Then it is a general impression through your trade that rain

water does not act upon lead?—I have never known it, and never heard that it acts upon lead. Mr. Melhuish.

Have you found that the Kentish Town water coming from the Hampstead ponds is harder than the New River water?—Yes, it is far harder. My cistern with New River water has been, as I have already said, 16 years in use, and has not been acted on at all; but I must repeat, as much depends on the quality of the lead itself, as upon the action of the water upon the lead.

William Howkins, Plumber to Mr. Short, of Kentish-town, examined.

You perform the plumbing work for Mr. Short?—I perform all his plumbing work: no one else is employed by him in this part of his trade. I have scarcely anything to do with the painting. Mr. Howkins.

Have you much experience of plumbing?—I have very great experience in it; I have been with Mr. Short during the last 14 years, and he has the principal plumbing work of Kentish-town.

From what sources is Kentish-town supplied with water?—From the Hampstead ponds.

How is this water conveyed from the ponds into the houses?—By a 12-inch main pipe, with smaller pipes of 4 inches, and pipes of three-quarters of an inch to convey the water into the houses.

What are those pipes composed of?—The main and service-pipes are iron, and the smaller pipes, that is, the three-quarter inch pipes, are lead, which are soldered on to a brass funnel, by which the water is conveyed into the interior of the houses.

How often is the water laid on?—Three times a week.

How long on an average does the water continue to flow?—From three-quarters of an hour to an hour.

What are the receptacles in general use for storing the water?—Butts, and cisterns of stone, lead, and zinc.

Have you, from your own observation, found the water to exert any action on these receptacles?—The water has scarcely any perceptible action on any of these, excepting on the leaden cisterns.

What have you observed to be the action of the Hampstead pond water on leaden cisterns?—Its effect is to corrode the bottoms of the cisterns very much, making holes in them, and thus rendering them leaky, and of no service without constant repair.

How long will a new leaden cistern last without any appearance of corrosion?—About two months.

From what circumstances do you conclude that the water acts upon the cistern in so short a time?—From its leaving a white substance at the bottom of the cistern, which substance when dried becomes a powder; and if the cistern is not kept constantly cleansed, this corrosion will eat its way completely through the lead, so as to render the cistern leaky.

In general how long will it take to corrode completely through the bottom of the cistern?—It acts chiefly at the edge of the solder; if not disturbed it may not be eaten through for two or three years. The matter corroded is so hard, as to bear a hair brush pulled strongly

Mr. Howkins.

over it; but when once removed, it is found that the lead is completely eaten through underneath.

Then a leaden cistern in Kentish-town does not last very long?—No, not without repairing; but if washed out constantly,—say every six weeks,—a cistern may last six or seven years. I have myself an instance of this in a cistern which I have attended to myself, and have regularly cleansed every six weeks. The bottom of this cistern has lasted to my own knowledge—for I put the bottom in myself—seven years.

It has been stated that coating the bottom of the cistern with a thick layer of paint will defend it from the action of the water. Do you think this would afford a protection?—I have had no experience of that; but I have myself made a compost consisting of bees' wax, resin, and mutton suet boiled together and spread while hot over the bottom of the cistern, which has answered effectually, having to my own knowledge succeeded in preserving a cistern eight or ten years.

But supposing no particular care were taken of a cistern, how long would it last without being corroded quite through?—That would depend on the substance of the lead.

Supposing it to be made of the ordinary substance?—We usually make it of six pounds to the square foot for Kentish-town wear.

Then suppose a cistern made of lead six pounds to the square foot, how long would this last in Kentish-town, no particular care being taken of it?—From one to two years before it would be eaten through.

Suppose a cistern made of lead exactly of the same quality and thickness, that is six pounds to the square foot, to contain rain water instead of Hampstead pond water, how long would that last without being corroded through?—The rain water would have no effect at all upon it. By mere wear it may produce some effect in twenty years, but as far as my observation may enable me to judge, it would go on year after year without any sensible effect being produced upon it. I have myself cleaned out rain-water cisterns when they have been inches deep of sediment at the bottom, consisting of all sorts of filth from the roof, and so on, but have always found them perfectly sound and free from any corrosion.

Have you had any opportunity of observing the action of lead on the service-pipes?—The earth, or the substances in the ground which may be in contact with the pipe, may perish the lead, but I have never observed any action of the water itself upon it.

This you say of the lead pipes distributing the Hampstead pond water?—Yes.

Have you had any opportunity of observing the action of rain water upon leaden pipes?—It has no action whatever upon them. I have myself taken down leaden pipes transmitting rain water for forty years, and the lead then appeared perfectly sound, presenting no appearance whatever of any action upon it.

Then as the general result of your observation and experience, you would say that hard water acts upon lead in a greater degree than soft water?—That is just what I have always observed.

Mr. Griffiths, Journeyman Plumber. Mr. Griffiths.

Where have you worked ?—Eleven or twelve years in London; at Kingston, four years.

What have you observed as to the effect of hard water on leaden cisterns ?—The harder the water the more it acts on lead; the softer, the less it acts.

How does the hard water act ?—In eating away the cistern. It generally eats away round the solder first, because that is the harder metal.

Do you generally find the hardest metal first acted upon ?—There are various sorts of lead; I have generally observed the hardest metal first acted upon.

Do you mean the hardest metal, not at the solder, but at the surface ?—Yes.

Have you ever observed the action of waters on the inside of pipes ?—No, we never cut them open; I never had the curiosity to look in them to see. But we observe the action of things on the outside of pipes. Lime acts very powerfully on pipes. Thus, if we carry a lead pipe through a wall which has lime in it, the lime eats away and destroys it. Some of the clays act on the outside of lead; the yellow clay eats it away soon; we don't find the blue clays act so much upon lead pipes, but that depends upon the different parts of the country where the clay is; in some parts of the country blue clay will act on leaden pipes. In some parts of the country yellow clay does not act so much upon lead as in others.

How do you find leaden pipes affected which go on the outside of premises, and are only exposed to the action of rain, such as leaden pipes crossing areas ?—I never knew any damage through rain in my life; if there is anything the matter with them, it is generally the frost which causes it, and they are very little acted upon in the way of decay.

How do leaden gutters go ?—It is generally the sun which acts upon them; it expands them and cracks them. They decay generally from beneath by old age; underneath very old leaden gutters we sometimes find the lead decayed away; it is in a white powder; we seldom find any decay on the top side.

On the whole, then, you find very little action upon lead from rain-water ?—I never observed any, not a bit of difference where the water must have run over one part of the surface more than the rest.

LETTER from WILLIAM LEE, Esq.

DEAR SIR,

Sheffield, March 14th, 1848.

I HAVE been unable before now to give you the information you asked for respecting street-cleansing, &c., by the hose and jet. You will perceive that some little time was necessary in order to answer your inquiries satisfactorily. This may excuse for the delay. Mr. Lee.

Messrs. Guest and Chrimes, of Rotherham, are patentees of a tap for the discharge of water at high pressures. They called upon me in February last, with an adaptation of their invention to the purpose of a fire plug and stand pipe, and expressed a wish to make an experiment with it.

Mr. Lee.

As their object was to show its powers to extinguish fires, we selected Church-street, one of the most public thoroughfares in the town, and containing the hall of the Corporation of Cutlers, a rather lofty building. At my request, the apparatus was applied with the most perfect success to the cleansing of the street; the Mayor, the Town Regent, and many other influential persons were present. The hose was of leather, 3 inches diameter, and about 60 yards long, with a discharge pipe 1¼ inch diameter. The carriage way is from 20 to 24 feet wide, and about 150 yards long. It was washed almost as clean as a house-floor in five minutes. The surface of the reservoir is 350 feet higher than the point of discharge, and 2557 yards distant from it. The time occupied, and the efficacy of the cleansing experiment, depended, of course, upon the quantity and force of the water, and not, to any material extent, upon the use of Messrs. Guest and Chrimes's stand pipe. The apparatus will, however, be very useful where a constant supply of water at high pressure is given, and deserves a brief description.

It consists of two parts; one of which, containing a female screw and closed valve, is to replace the common fire plug, to be fast to the main pipe, and to be covered, when not in use, by a metal cap. The other part is the stand pipe—a copper cylinder about 2 feet long, which screws on to the fire plug. On the sides of the cylinder, about 6 inches from the top, are two arms at *right angles*, and each about 4 inches long, with screws to attach the hose. A screw piston about half an inch in diameter, with crutch handle, working in a stuffing box, passes through the centre of the upright cylinder, and opens or shuts the valve of the fire plug. Its advantages are, that it can be applied to the mains, and used with great readiness, without the assistance of the turncock, at any amount of vertical pressure. With the ordinary plug it is necessary, on the discovery of a fire to seek the turncock, who is obliged, if the mains are full and a constant supply given, to seek the nearest main-tap, and turn off the water until the fire plug is opened and the hose attached, and then to go back and turn it on again. In the midst of the confusion much valuable time is thus added to that already lost in procuring the engines, and the jet is at last directed, as a matter of prudence, to the preservation of adjoining buildings, leaving that in which the fire originated to certain destruction. If this apparatus were at hand two men could have it in full operation in less than two minutes. By a slight increase in the diameter of the stand pipe, four arms might be connected with it, and four jets, managed by as many men, would throw into any building torrents of water sufficient to extinguish speedily any fire that had not been long raging.

It will be obvious that this saving of time and labour would also be of great importance as affecting the cost of any system of public cleansing by the agency of water. In consequence of the gradual opening and closing of the valve there is much less danger of bursting the hose by a sudden rush of water, or of damage to the pipes by its recoil, than with any other apparatus I have seen. The wear and tear of hose under great pressure must be a considerable item in *any* system of public cleansing. In extinguishing fires the hose is frequently burst, and before other hose can be attached, irreparable mischief is done by the raging element.

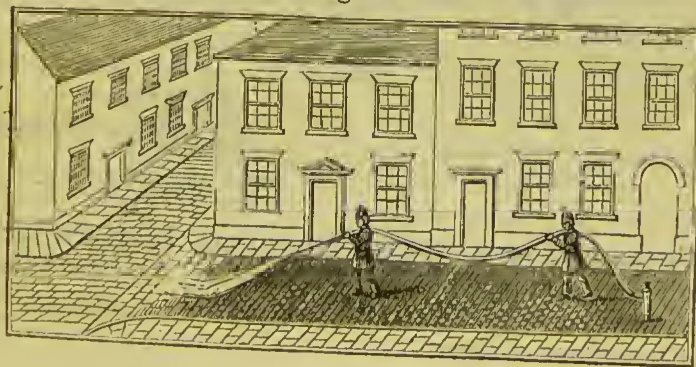
This, therefore, is a great advantage possessed by the apparatus in question. Mr. Lee.

A serious defect in Messrs. Guest and Chrimes's invention is, that the water has to pass one right angle at the fire plug, and another at the insertion of the arm in the stand pipe. The time necessary for the discharge of a given quantity of water through a straight pipe being 1, the time for an equal quantity through a pipe of the same length and diameter, having a curve of 90°, would be 1·11, and with a right angle, 1·57. Two right angles would therefore increase the time to 2·464. As the *quantities* of water discharged in equal times by the same orifice, with the same length and form of pipes, under different pressures, are nearly as the square roots of the corresponding pressures; so, the *times* during which equal quantities of water are discharged, under the same circumstances, are nearly in the inverse ratio of the square roots of the corresponding pressures. Consequently, with the same discharge, from the same orifice *under the same vertical head*, and with a pipe of equal length and form, *a given increase of time* will indicate the amount of retardation due to any flexures, curves, or angles of the pipe. And, the retardation caused by any such flexures, curves or angles in the pipe, *will be equivalent to a certain diminution of the vertical pressure*, easily ascertained. In the experiment in question, the jet from a 1¼ inch discharge pipe with 350 feet pressure rose only to about 60 feet vertical height, in consequence of the two right angles in the apparatus.

The time for a straight pipe, being, as already stated, 1, two curved junctions would have only increased it to 1·23, while the right angle prolonged it to 2·464. The form of the pipe therefore becomes most important in any system of street-cleansing, not only as to the direct economy of time and labour, but also in reference to the power of the water in effectually removing the refuse.

The form of the pipe is no less important when applied to the extinguishing of fires, because with curved junctions, not only will the jet rise to nearly twice the height, under the same pressure, but the hose and stand-pipe will be available without fire engines, under about half the vertical pressure necessary with right angles; and, not the least consideration is, that with an equal pressure, nearly double the quantity of water would be impelled to the same height in a given time. I suggested to Messrs. Guest and Chrimes the substitution of curved junctions, and pointed out these advantages, and am glad to hear they are about to adopt my recommendation.

Fig. 1.



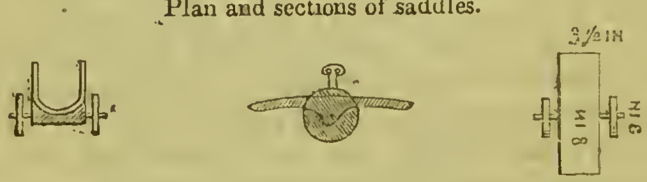
Mr. Lee.

Sketch No. 1. shews the manner in which the experiment was performed, which was clumsy enough, but the best that could be adopted under the circumstances. The hose was stretched from the stand-pipe up the street, and the foreman having placed the end of the hose upon his shoulder with the discharge pipe pointing to the pavement, at a distance of about nine feet before him, the plug was opened, and he commenced walking down the street, moving the jet slightly from side to side. The weight and rush of the water through the hose was however too much for one man, and he was therefore assisted by a second, taking up the hose in a similar manner, and walking at a distance of two or three yards behind him. The work was laborious, but I have no doubt that with the substitution of curved junctions to the stand pipe, giving a greater force to the water, and the adoption of some contrivance similar to what I have figured in the sketch No. 2, the work would be done as effectually, even in less time, and with perhaps half the expenditure of physical strength.

Fig. 2.

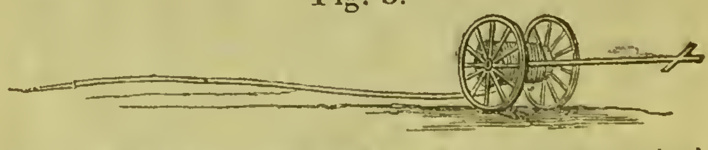
The sketch shews a series of saddles, to be attached to the hose at regular distances, and moving on small wheels, so as to take off a great portion of the friction which has to be overcome in dragging the full hose along the pavement. The sketch will I think explain itself without further remarks, and if it is not the best thing that can be, may lead to something better from a wiser head. This sketch also shows the curved junctions for the fire plug and stand-pipe.

Plan and sections of saddles.



The third sketch shows a light carriage which would enable a man to run at great speed with the hose and all the necessary apparatus for extinguishing fires.

Fig. 3.



It is little more than a wooden drum from 18 to 24 inches in diameter, which can be made either to revolve with the wheels or to remain stationary, it would be further useful in unfolding and folding the hose without loss of time.

There would be a peg or button upon the drum, to which a loop at the end of the hose nearest the stand-pipe would be attached, and the movement of the carriage, however rapid, along the line of the hose, would wind it upon the drum. The drum would now be thrown out of gear with the wheels, and the carriage and apparatus removed to another place. On reaching its destination, it will be evident that if the drum be again put into gear with the wheels, and the carriage drawn in a contrary direction to the former, the hose will be unwound and ready to be attached to the stand-pipe without delay. Mr. Lee.

We now come to consider the quantity of water necessary for public cleansing with the hose and jet. The line of pipes leading to Church-street, used for the experiment, is 12 inches in diameter, with an area of 113·097 square inches when it leaves the reservoir. It is afterwards reduced to 9 inches, area 63·617. The hose is 3 inches, area 12·566; and the discharge pipe $1\frac{1}{4}$ inches, area 1·2271. There are branches from the main in its course, and also curves and flexures both vertical and horizontal, the sines of all which have to be accounted for, as reducing the velocity of the stream. These circumstances added to the loss caused by the right angles in the fire-plug and stand-pipe, already alluded to, very much impede the discharge. The quantity of water actually used during the five minutes was 27·19 cubic feet, or about 170 gallons. I am disposed to add half as much more for waste in emptying the hose, &c., making 255 gallons for the 150 yards of street, this is equal to 2992 gallons per mile.

I have stated that the jet was in operation for five minutes in cleansing this street. In order to make a safe estimate I allow five minutes more for unfolding and *fixing* the apparatus; five minutes for *unfixing*, &c., and five minutes for removing to the next plug, or point of operation, making altogether 20 minutes for 150 yards in length. Equal to rather more than $2\frac{1}{2}$ miles in length per day of 10 working hours. With improvement in the hose and means of transit, such as I have suggested, two men would be sufficient for one set of stand-pipe, hose and jet, and would probably execute a greater length of work.

I will now endeavour to apply the data obtained to the cleansing of a town like Sheffield. No one will doubt if two men can with ease cleanse $2\frac{1}{2}$ miles of road per day, *including the carrying away of the refuse*, that this is the most *economical* mode of street-cleansing that can be adopted, even if we leave out of consideration, entirely, the fact that the work is done more perfectly by the agency of water than by any other means. All public highways, therefore, in all large towns, ought to be cleansed with the hose and jet as a matter of economy, exclusive of sanitary considerations. Unfortunately it will be long before this is practicable in Sheffield. The roads outside the dense population are numerous, and without either pipes to convey the water, or sewers to remove the refuse. I have been compelled, therefore, to consider the question as a sanitary regulation only, and to confine my estimate to the densely populated part of the borough. The following table shows the comparative extent to which this method of public cleansing could be readily applied in the six townships which constitute the borough of Sheffield :—

Mr. Lee.

TOWNSHIP.	Total length of Public Carriage Ways.	Length to be cleansed with water three times per week.	Length to be cleansed with water twice per week.	Length to be cleansed with water once per week.	Total length of Public Highways to be cleansed with water.
	Miles.	Miles.	Miles.	Miles.	Miles.
Sheffield	$31\frac{1}{2}$	6	10	9	25
Ecclesall Bierlow . . .	$26\frac{3}{4}$	2	6	4	12
Brightside Bierlow . . .	20	1	$1\frac{1}{2}$	$1\frac{1}{2}$	4
Nether Hallam	Suppose 10	1	1	1	3
Attercliff-cum-Darnall. .	,, $3\frac{1}{2}$	..	$2\frac{1}{2}$	$\frac{1}{2}$	3
Upper Hallam	,, 12	..	..	..	..
Total in the Borough .	$103\frac{3}{4}$	10	21	16	47

Thus, it appears, that 47 miles, or nearly half of the public highways in the whole borough might, without difficulty, be effectually cleansed in this manner. Ten miles three times a week, equal 30 miles; 21 miles twice per week, equal 42 miles; and 16 miles once per week; making a total of 88 miles per week; or 4576 miles per annum. This at 3000 gallons of water per mile would require 13,728,000 gallons of water per annum. At *one penny* per thousand gallons, the price at which I have shown in the Report on the sanitary condition of Sheffield, an abundant supply of water could be obtained, the quantity necessary for the purpose would cost 57*l.* 4*s.* per annum.

At $6\frac{1}{2}$*d.* per thousand gallons, the price obtained by the Water-works Company, the same quantity would amount to 371*l.* 16*s.* per annum.

I now proceed to the cost of labour:—4576 miles per annum is equal to $14\frac{2}{3}$ miles for each working day, or to six sets of two men cleansing $2\frac{1}{2}$ miles per day each set. To these must be added three horses and carts, and three carters, for the removal of such debris as cannot be washed away, and for such parts of the town as cannot be cleansed by this system, making a total of 15 men. Their wages I would fix at 50*l.* per annum each. Taking into account, in addition, the cost and repair of hose, horses and carts, &c., the estimate given at page 110 of the report already alluded to is correct. It is as follows:—

	£.	s.	d.
Annual interest upon the first cost of hose and pipes, three horses and carts, &c.	30	0	0
Fifteen men's wages	750	0	0
Three horses' provender	150	0	0
Wear, tear, and depreciation of hose, &c.	250	0	0
Management and incidentals, say	120	0	0
	£1,300	0	0

It is there stated that the estimate is made on the supposition that the water supply was at the public cost. I have no doubt that with the use of canvass hose, the amount allowed in the estimate for wear and tear would more than cover the 57*l.* 4*s.* required for water;—but even with this sum added, the statement in the report would not be affected,

namely, that *this would be about an average of one shilling per annum for each house in the borough.* Mr. Lee.

The principal thoroughfares could be thus made perfectly clean, three times every week, before business hours, and the minor streets and lanes twice, or once per week, at later hours in the day; by the agency of an abundant supply of water, *at less than half the sum necessary for the cartage alone, of an equal quantity of refuse in a solid or semi-fluid condition.*

I have only to add that I have tried Merryweather's Patent Spreading Apparatus, with which you are probably acquainted, and that I think it an admirable contrivance for washing the fronts of buildings, and watering streets with the hose and jet, wherever a constant supply of water has been obtained.

I am, &c.,

WILLIAM LEE.

Edwin Chadwick, Esq.,
Gwydyr House, Whitehall.

LETTER from MR. THOMAS SPENCER.

SIR, *Liverpool, August* 2, 1850.

I HAVE just seen a Report of Mr. Wicksteed's to the Corporation of Leicester on the supply of water to that borough. It contains a paper by Professors Aikin and Taylor, of Guy's Hospital, which is divided into "Remarks on the Purity of Water," and "On Dr. Clarke's Soap Test." I have so recently had the honour of laying a paper before your Board on one of those subjects, and in which I arrive at conclusions so very different from these gentlemen, that I trust to be allowed to make a few observations on their paper. At the same time I beg to assure you, Sir, that it is with great reluctance I thus venture to dissent in opinion with gentlemen of their professional standing. Mr. Spencer.

Although my paper relates more particularly to the action of lead on various qualities of water, yet the general views of these chemists are—on this subject—so much at variance with my own, that I offer less apology for the remarks I shall make on other parts of their paper. More especially as it seems to be altogether grounded upon a passage which occurs in a report of Mr. Ranger's made to the General Board of Health in 1849 on the water-supply of Leicester. In his report this gentleman recommends the use of pure soft water in the following terms:—"The supply must be pure and wholesome,—*i. e.*, free from vegetable, animal, and mineral matter, and at the same time not flat, but well aerated." To practical men, engineers, and others, who do not profess to be chemists in the strict sense of the term, the intention and object of this passage ought, and doubtless would be, clear enough. Professors Aikin and Taylor, however, take exception to it because of its obscurity; and being at some loss, as it appears, to discover its precise meaning, they ultimately find in it an implied recommendation, by Mr. Ranger, to use "*absolutely pure*" or distilled water, or that which they tell us is the same thing, "rain water collected in clean glass vessels."

Now, I must say that this is altogether a gratuitous conversion of

Mr. Spencer. the passage, and which seems to have been made by these gentlemen for the purpose only, of recording their own opinions as to the superior wholesomeness of *hard* in contradistinction to pure *soft water*. As a proof of which they continue to say that "distilled, or rain water, collected in the manner described" (described by themselves, *not* by Mr. Ranger), "although absolutely pure, would not be proper for a diet water." To which they add, that "this fact is well known to all professional men," (page 82.). But a little further on they assure us, that water of this abstract degree of purity "does not exist on the surface of the globe, and that to seek for it would be needless waste of time." Now as the last sentence quoted contains a fact, which, in its strict sense, all will be ready enough to admit—Mr. Ranger amongst others—were it not with the object of overturning it, upon what other principle do they set it up; this being a standard of purity, which, on their own showing, nowhere exists in nature, and which, it is therefore clear, could not have been intended by Mr. Ranger? Were the question to be discussed at all, it surely would have been fairer to have taken a water of such purity and softness as came within the range of ordinary circumstances to obtain.

I must confess that were I called on by a board of chemists to point out a natural site whence water might be obtained of sufficient purity for the more refined laboratory purposes, I should concur with Messrs. Aikin and Taylor that we could hardly expect to find such a natural supply; but on the other hand, had I to report to a General Board with respect to a supply of *pure* water for a town, and which should be "free from animal, vegetable, and mineral matter," and which should also be "well aerated," I should be at no loss to point out several places in England, where ample supplies of water, fulfilling these conditions, might be obtained. Be it observed, however, that as a chemist, I should expect to find in all of them a few grains, more or less, of mineral substance, with, perhaps, previous to filtration, a trace of vegetable matter. Still I should consider such water as being practically pure, and as such, would not hesitate so to report. The water of the upper part of Bala lake, I have found to contain little more than one grain of solid matter to the gallon, nor can it be said that it is not well aerated, or that it is flat, yet it is difficult to discover in it, more than a fractional trace of carbonates of any kind. The waters of the Millstone grit districts of Lancashire are, in this sense also, *pure waters*, and are unquestionably well aerated, yet some of them contain little more than a grain of carbonate of lime to the gallon. I might multiply such instances; but these are surely sufficient to show that pure and well aerated water may be obtained without travelling very far over "the surface of the globe."

As to the universal opinion which we are told prevails amongst medical men as to the unwholesomeness of pure water, perhaps I may not be expected to say much. My personal experience, however, would go far to contradict it. Nor need I say to you, Sir, that it is the acknowledged opinion of a large part of that profession, that water *is* wholesome as a dietary water, *in proportion to its purity*. Where I have found opinions to prevail of an opposite character, they have been, not unfrequently, coupled with vague notions, that the lime contained in hard water was necessary for the structural renovation of the animal system.

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Where it is so positively affirmed that pure water is an improper dietary water, surely an opinion so paradoxical ought to have been accompanied with more definite reasons, either medical or chemical. On a subject of such importance, we ought to claim not to be left in the dark; we are surely warranted in requiring this much, upon recollecting that so large a proportion of the inhabitants of the globe are somehow enabled to subsist on comparatively pure water, and which is derived not remotely from rain. Neither have I heard that any of the prevailing diseases of those countries are attributable to the freedom of the water from mineral impurity. On the other hand, I know it to be a fact, that the mineral impurities subsisting in the well or spring water, which we are at present compelled to use, does act medicinally on persons habituated to a purer water. They do not consider rain water collected on a roof as either flat or vapid; but when cool prefer it to common spring water. Instances of this description are so numerous, that it becomes specially incumbent on those who hold pure water to be so unhealthy, to instruct us not only why it is so, but also to point out the peculiar conditions which enable us to take it so largely into the system with impunity. One cannot avoid remembering, that the Malvern waters are most grateful to the palate, while they are the healthiest and *purest*, perhaps in England; their specific gravity being 1·002 or near absolute purity. The Matlock waters are little less pure, and equally healthy.

I am much at a loss to conjecture from what source Messrs. Aikin and Taylor have derived their ideas of the process by which potable spring waters become aerated in nature; these are of course entirely apart from calcareous waters so-called, which being unfit for use, are beside the question. Their explanation is to the following effect:—"Water," say they, "which is entirely free from animal, vegetable, or mineral matter—*i. e.*, distilled water, must necessarily be flat, and cannot well be aerated. The carbonate of lime constituting the greater part of the mineral matter in wholesome spring water, acts as a basis for fixing carbonic acid, and it therefore serves to aerate the water, and deprive it of that flatness which it would otherwise possess." I am much inclined to think that when framing this explanation, they had artificially aerated water only in view. I am unable to account for it on any other supposition, because, from this it would appear evident, that they intend a well aerated water, to mean, water impregnated with carbonic acid only. Although the term may have a certain degree of correctness, when applied to the refreshing draughts sold in the soda water shops of the Metropolis, yet it is obviously not the intention of the term in reference to the water supply of a town. Well aerated water, means literally, water which shall contain a due proportion of pure atmospheric air. The water of a running stream, therefore, is a well aerated water, so also is fresh fallen rain; but in neither case are they well aerated, because of carbonic acid, but they are so *only*, in virtue of the air, which they contain, constituted as we find it in the atmosphere. It is also important to bear in mind that, the purer water is, the greater its capacity to contain air; or in other words, to become well aerated, in the true sense. Suppose, however, it were considered necessary to health, to have water while in its natural state, well aerated with carbonic acid, instead of the usual proportion of pure air as found in the atmosphere, it is exceedingly difficult to comprehend how the acid is to be furnished by the process pointed out. It is true, these gentlemen inform us, that

Mr. Spencer. wholesome water ought to contain carbonate of lime, because this substance "acts as a basis for fixing carbonic acid, and therefore serves to aerate the water." But how carbonic acid can aerate water, *i. e.*, impregnate it with carbonic acid, while the *same* acid is *fixed* in the carbonate of lime, it is left for us to discover! We are also left in the dark as to the means or when it becomes liberated. Strictly speaking, carbonate of lime, as such, is never found as a *chemical* constituent of water. I am aware, however, that in what these gentlemen term "wholesome spring-water," super-carbonate of lime is often found to a large extent, and without doubt, they meant this substance, while omitting, as is not unusual, the technical prefix, it being well known that where frée carbonic acid exists, carbonate of lime cannot remain even in mechanical suspension. Still the difficulty is not lessened, for should the super-carbonate give up its acid to aerate the water, its own chemical existence in the water is thereby destroyed. It might as well be said, that sulphate of soda acidulates, as that the carbonate of lime, under ordinary natural circumstances, aerates water.

This becomes obvious when it is considered that the extra equivalent of carbonic acid, which renders the simple carbonate soluble, becomes fixed as soon as it contributes to form the super-carbonate. When set free, however, *chalk is precipitated.* It is also true that the acid may be found in a state of freedom along with the super-carbonate, but then it is wholly independent of this substance, and in such a case it would be present in greater amount were the lime absent. I mention these, not so much by way of correcting mistakes or merely pointing out error, as that would hardly be in place here, but more to show the non-necessity for lime in water, even should it be to serve the purposes pointed out by these gentlemen. When it is asserted, however, that it is conducive to health to have a certain quantity of lime in water, although perhaps not highly impressed with the efficacy of the prescription, yet even then I imagine I can comprehend the prescriber. But when I am told that this lime is required for the purpose of aerating the water with carbonic acid, to prevent it from becoming flat, then, on chemical grounds, I begin to suspect some misapprehension, because *the acid which is so combined with lime can produce no aerating effect on the water.*

Where so much importance is attached to carbonic acid, it ought to be recollected by chemists that its presence in potable spring-water in no way depends on carbonate of lime. Strictly speaking, it is very much the contrary. When this acid is found in water, it is derived from rain in the first instance; the rain absorbing the acid in its descent through the atmosphere. But were there no carbonates in the stratification on which rain falls, and out of which it again springs, water would in that case contain a much larger proportion of this gaseous acid. Carbonate of lime, therefore, so far from contributing to preserve this acid, practically destroys it, by the formation of a new substance, which would appear to serve no other purpose than to render water hard. I have had to examine water which after evaporation rendered 20 grains of dry carbonate of lime to the gallon, yet at a summer temperature of 80° to 85° Faht., with delicate tests, it gave no indications of free carbonic acid.

I now arrive at the observations of Messrs. Aikin and Taylor, on the action of lead and water. The subject is treated less in detail than

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might have been desired. All that can be tangibly dealt with is contained in the following passage. "There is another most serious consideration (say they) connected with the use of distilled or rain-water, namely, that in a direct ratio to its purity, or freedom from vegetable, animal, or mineral matter, it is liable to become poisoned by contact with lead, as by circulation through leaden pipes, or by being collected in leaden cisterns" (page 83.) This passage, it will be observed, is not in perfect keeping with the context, while it would appear to be mainly grounded upon experiments with lead and distilled water *only*. It will be remembered that they have already said, that water, having the purity of distilled water, nowhere "exists on the face of the globe, and that to search for it would be a needless waste of time," while we are now informed that water of this *same purity* becomes poisoned with lead. Be it so. But the question being altogether one of practice, is it consistent or reasonable to sound a practical alarm founded on the action of a theoretical water; especially when these gentlemen admit 'that such water is nowhere to be found? Were it apparent, that water so pure was to be met with at every turn, then the utility of the warning might be better seen. It is said, however, that the poison becomes diffused in the *direct* ratio of the purity of the water. It is to be regretted that this is not shown by experiment, or by more detailed examples of practice with rain or slightly hard water. Those which are mentioned prove little or nothing, as, unless an exact analysis were given of the constituents of the waters with which the alleged accidents are said to have occurred, we are in the dark as to their real nature. To prove that this action is by no means in a direct ratio with the purity of the water, it may be only necessary to state, that two grains of sulphate of lime (gypsum), or half the quantity of silica, to the gallon, will do more to prevent it than ten grains of chloride of calcium or sodium (common salt). This action, therefore, cannot be said to take place in the ratio of the purity of water, unless it were shown that all waters had similar chemical constituents, and which were held in like proportions in all; and that the only difference was in the quantity held by each. But taking waters as they are usually found, *there is a point*, and that not a very high one, in the scale of mineral impurity, when this action upon lead altogether ceases.

As I have already treated of the action which ensues with very hard water when exposed to the action of air in open cisterns, I may be allowed to make a few additional observations on the action of soft water while *enclosed* in leaden service-pipes, and which are consequently free from the action of extraneous air. Cisterns, I may add, of any description are altogether incompatible with a constant supply.

It has been long known that an action will take place when *absolutely pure* water is in contact with lead. Most experimentalists agree in considering it to be the formation of a hydrated oxide of lead, which readily becomes a carbonate on exposure to air. *These substances are insoluble in pure water*, or, in other words, they are removable by filtration; a fact which, though doubted by some, is yet susceptible of easy proof. Where it appears to have failed the filter has been imperfect. Where water is caught upon a slated roof in a rural district, it is almost absolutely pure. Such water, if kept in an open cistern, would act upon *new lead*, that is, the highly comminuted powder of

Mr. Spencer. this metal would be found in the water, but *in an insoluble state.* Where circumstances render it necessary to use water of this character, where stored in a leaden cistern, or after having passed through leaden pipes, it would then be prudent to subject it to filtration. Although this process usually involves the use of cumbrous vessels, and but a tardy supply withal, yet both these inconveniences may be entirely got rid of. One of the best I have seen is "Foster's Patent Pressure Filter," which, although calculated to deliver the largest quantities, yet for domestic use need not occupy more space than the usual ball-cock of a cistern. Apart from its compactness, I have found that this filter completely arrests the passage of lead, where, for the purposes of experiment, I have caused its oxide to be mechanically diffused in water. This filter is screwed to the delivering end of the service-pipe, and there it is obvious no water need be used without having passed through it; moreover, the solid impurities which necessarily collect on the filter, are cleansed from it by the most simple yet effectual means.

With respect to the real nature of the action of water upon lead, there is ground for reasonable doubt, some assuming it to be a diffusion of particles of highly comminuted lead, which diffuse themselves in the water, while most suppose it to be the formation of an oxide. Practically, this makes little difference. Where experiments are made in open vessels, the formation of this substance is observed to be much more rapid than where the surface of the water is kept free from extraneous air; a fact which illustrates the difference of action in a closed pipe as compared with an open cistern. So far, then, with regard to *distilled water*, but the results are altogether different when made with water having one or two degrees of hardness, a water which I would term, in reference to the supply of a town, "pure soft water," *i. e.*, water as pure and soft as it is practically possible to be obtained in quantity sufficient to supply a town; such water would contain, as the case might be, 5, 6, or 7 grains of mineral impurity to the gallon. Water of this character may be had from gathering-grounds in rural but not highly cultivated districts, where lime is not a predominating ingredient in the stratification. Although a healthy pure soft water may be thus obtained, well aerated, *with pure air*, yet under such circumstances, in England it is little likely to be of that degree of purity which will act upon lead. The question, however, has now become almost beyond discussion, inasmuch as it can be resolved by the results of practice. In consequence of the growth of population and the consequent contamination of their home supplies, many towns of England and Scotland have of late years been compelled to resort to distances for purer and better water. As they have increased in population, with scarcely an exception, all large towns, both ancient and modern, have been obliged at one period or another to adopt a similar course, few of them being so fortunately situated as to render an extraneous supply unnecessary. There are at present above 20 towns in the United Kingdom with upwards of 2,000,000 of population, that are supplied with nearly pure soft water, the source of supply being, in most cases, country districts at from 4 to 10 or 20 miles distance, and which in nearly every case is constant; leaden cisterns, therefore, are not required.

What then is the nature of the experience we derive from the prac-

tice of these towns? I have made a good deal of direct inquiry, and have had information from the best sources, but have not heard of any case even of suspected indisposition which has arisen from the use of lead pipes *kept always charged with water.* On the contrary, the water itself is considered by all who have recently experienced its use as a great blessing. Such I consider to be the best answer to this unfounded alarm. I may also state that I have made experiments with several samples of soft waters procured from different localities without detecting this noxious action with lead. It is true that none of them were as free from mineral impurity as rain water, caught on a clean slated roof, but they were such waters as may be found flowing in the pure brooks of country districts in many places of the kingdom. As an example, I subjoin the results of an analysis of the water of a stream in the Rivington district of Lancashire, from whence Liverpool is about to be supplied. It fairly represents the other brooks in the same district, having examined several of them.

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Carbonate of lime . . .	1·300
,, magnesia . .	0·500
Chloride of sodium . . .	2·150
Silica	0·850
Oxide of iron	0·200
Organic matter	0·750
Grains of solid contents per gallon .	5·750

The hardness is equal to $1\frac{1}{2}$ degrees.

This water has no action on lead, although it is very pure and very soft. Thus we see that a trifling quantity of mineral matter altogether prevents this action upon lead. I have made several experiments with other waters of different degrees of purity, with the view of determining the minimum quantity of matter in chemical solution which would altogether prevent this action. With this view I subjected the two following waters to analysis, the results of which I subjoin.

Surface Water from Red Sandstone.

	Grains.
Carbonate of lime . . .	2·10
Chloride of sodium . . .	1·06
Sulphate of soda . . .	0·80
Silica	0·20
Loss and organic matter . .	1·03
Grains in each gallon . .	6·09

Hardness of this water, 2·4 degrees.

Water from a Brook near Bangor, Wales.

Sulphate of lime	1·40
Sulphate of magnesia . . .	0·30
Chloride of sodium . . .	1·40
Silica	0·20
Organic matter, loss . . .	0·90
Grains in each gallon . .	4·20

Hardness, 1·90.

Mr. Spencer. I should take it for granted that few would hesitate to call these pure, and soft waters, "free from animal, vegetable, and mineral matter." Yet I have kept slips of lead in them for several weeks without suffering any change; nor afterwards could lead be detected in the water; the vessel in which the experiment was made, being kept close. Purer water than this, I think, we are little likely to obtain on a large scale. But even where it contains seven or eight grains of mineral matter, with from three to four degrees of hardness, still it is to be considered comparatively a pure soft water, and most desirable for the supply of a town. But let us suppose, on the other hand, that it were possible to obtain water so absolutely pure and well aerated as to render its action on lead inevitable, surely it does not follow, that we are absolutely bound to the use of leaden pipes for its distribution, the more especially when so many substituting substances are so frequently presenting themselves. This great boon to health and domestic comfort, to say nothing of its acknowledged economy, must not be so readily given up. Our greatest cause of regret ought to be, that water of such absolute purity is not likely to be obtained.

I shall now offer a few words on Messrs. Aikin and Taylor's remarks on Dr. Clarke's soap test. Those who use this test do so only for the purpose of readily determining the quantity of soap a water decomposes before becoming detergent, and *not* as these gentlemen state, *to determine its purity*. Neither have I heard that a low degree in the scale of hardness necessarily implies a high degree of purity. I can imagine it, however, to be so considered by persons not professionally acquainted with the subject, but never by a chemist; yet we have it set down in page 87 of the Report, that "Dr. Clarke's soap test assumes to determine the purity of water by the qualities of '*hardness* and *softness*.'" Now, I think I am warranted in saying, that Messrs. Aikin and Taylor assume more than ever Dr. Clarke thought of claiming for the test, or any chemist who makes use of it. Yet these gentlemen in their remarks on the subject, speak as if all who use it, contend that *softness* according to the scale, and chemical purity, are convertible terms. It is quite true, however, that with the ordinary spring water of the south of England, where the hardness is chiefly derived from contact with calcareous earths, this test will roughly determine the mineral impurities they contain. I believe, that in the first instance, too high a degree of accuracy was claimed for the scale devised by Dr. Clarke, but this was in relation to the assumed fact, that each degree of hardness indicated the existence of a grain of carbonate of lime or chloride of calcium in the water. This however, was held to be so *irrespective of its purity or freedom from the other substances which it might contain*. But the fault which may be fairly urged is, that the scale was made with reference to salts of lime only, and that waters deriving their hardness from magnesian salts, were not taken into account. This is an important distinction no doubt, not only from the difference of the chemical equivalent of magnesia, as compared with lime, but from the different action its salts have upon soap. It followed, therefore, that in districts where the hardness of water is derived nearly as much from magnesia as it is from lime, that in those instances only, the scale is somewhat inaccurate. For For my own part, I have already had occasion to point this out in a

report made to the Liverpool Corporation, of the hardness of the waters of the surrounding district. But where hardness is derived from calcareous matters, the test itself, and the scale give results very close to the truth. Even Messrs. Aikin and Taylor themselves admit, that the former method of soap testing which took distilled water for unity, was a good and ready method of arriving at comparative results, in which opinion I entirely concur. Mr. Spencer.

I have the honour to be, Sir,

Your very obedient Servant,

THOMAS SPENCER.

Henry Austin, Esq.,
Gwydyr House, Whitehall.

James Temple, Esq., Writer to the Signet of Paisley, examined.

What experience has there been at Paisley of the public use of waters of different qualities?—Previously to the introduction of the new water supply, the water used was spring water and river water. The spring water taken from the wells was very hard; the river water was comparatively soft, and was used for washing. A supply was afterwards obtained of yet softer water from gathering grounds, the water at present in use being of only two degrees of hardness. An Act of Parliament was obtained to supply the town with river water, as being much softer than well water, but on ascertaining that a still softer water might be procured, the townspeople allowed the Act to expire without availing themselves of the powers conferred by it. This softer water, obtained from gathering grounds, is now in use, and is of two degrees of hardness. Mr. Temple.

What can you state as evidence of popular appreciation of the softer water now supplied?—The popular complaint is that it is sold at too high a price, and they think it no crime to steal it, and they do steal it whenever they can.

May they have well water or river water without stealing?—Yes; they may.

This soft water is, then, preferred to the well or river water?—Yes; for every purpose.

For drinking?—Yes, for drinking particularly: for myself, when I come to London I think I shall not get a good drink of water until I again return to Paisley.

Is the supply of water constant at Paisley?—Yes; by gravitation.

Is the soft water considered superior for tea and washing?—For tea, there is not a lady in Paisley who would not give testimony as to its superiority. We find also in washing that we have a great saving not only of soap, but also of the wear and tear of clothes, from the greater rubbing occasioned by hard water.

Have you perceived any effect of the introduction of softer and more palatable water on the habits of the population, as respects spirit-drinking?—There is certainly less drinking among the middle and upper classes than formerly, and probably some improvement in the lower classes.

Do you know what is the general medical impression as to the effect

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of the change of system?—They are unanimously in favour of the change. They all agree that calculous complaints have largely diminished since the introduction and use of the softer water. As illustrative of the public appreciation of the change, I may mention that there is now a town subscription in progress to erect a monument to Dr. Kerr, the gentleman who introduced the present soft water supply. It is considered to be a great blessing.

Dr. Shier, examined.

Dr. Shier.

You are the agricultural chemist to the colony of Demerara?—Yes; I am.

Have you been led to pay special attention to the qualities of water chemically, and for its practical and domestic use?—Yes; apart from the general interest of the subject, I was led to pay special attention to it from having been present at many of the experiments made by my friend Professor Clark, of Aberdeen, in relation to the qualities of water. I was led to pay attention to the sorts of water derived from particular geological formations, and examined many waters from streams and wells on the spot.

Since you have been at Demerara, have you had experience of the use of soft water for domestic purposes?—Yes; I have. In Demerara rain water is the sort chiefly used; the water is generally gathered from the roofs of houses; these are cleaner than in England, on account of the fuel consisting of wood or of wood charcoal; hence the roof water is obtained in greater purity: then the kitchens are all to leeward, and the roofs from which the rain water is obtained are to the windward, and little influenced by the smoke. Many careful people, after a long drought, let the first washings of the roof run off by a waste pipe. The tanks are covered.

Have you yourself drank the soft rain water habitually?—Yes; I have; we all do there: thus, every member of our legislative body, when the Court is in session, has his cold water guglet and tumbler placed on the table before him along with his portfolio and writing materials.

What is your experience or observation of the use of the soft water, as compared with the hard or chalk waters?—Everybody in the colony relishes cold soft water in preference to any other sort of water, and when they go elsewhere they perceive the difference very keenly. The use of the soft water renders them very sensitive to the qualities of other waters, and they become critical in a high degree in relation to them. In Bridgetown, Barbadoes, the quality of the water which is drank by the people there without notice is hard water from the coralline formation, was found by the Demerara people to be so disagreeable, that the proprietor of one of the hotels was induced to collect and preserve the rain water for use. The consequence was, that almost all Demerarians visiting the island go to reside at that hotel. Excepting a few instances where they use soft water, I have, since I left the colony, met with no water which has seemed to me to be good, except that which I met with at New York, where the people have recently obtained a supply of soft water derived from the primary formations, at the source of the Croton

river. Here, in London, the hard water which is in use is disagreeable to me to drink, and more so to wash with, at least that which we get at the Tavistock Hotel. I find that washing with the hard London water and soap results in a sort of anointing with an insoluble lime soap. Dr. Shier.

What circumstances do you consider exercise the most important influence in rendering a drinking water palateable?—First, temperature; and secondly, purity. I think temperature of the most importance, because the purest water drank at an improper temperature will be unpalateable.

What temperature have you found the best for drinking water?—In the tropics I have found that the reduction of about four degrees below the temperature of the atmosphere is sufficient to render water palateable, and we readily attain this by putting the water in porous earthen vessels exposed in the shade to the action of the sea-breeze.

Will not low or palateable temperature disguise the qualities of water?—To an extent. If you raise the temperature of a water you will bring out, or be able to perceive, any bad qualities it may have, much more than when it is cooled; but if two waters of equal temperature be used, the one soft and the other hard, a person who has been used to the soft water will readily detect the inferior taste of hard water.

What has been your observation as to the effect of the purity of water upon health?—I think the purity of the water has a very important effect on health; although not being a medical man, my opinion may not be of great value. The only fact which I can state is, that it is well known that cases of calculus complaints do not originate in the colony. When cases of stone or gravel occur in our hospitals, they are found in patients who have come from colonies where the water is hard. This fact has been confirmed to me by several of our leading medical men. I am aware that all medical men do not connect the disease with the nature of the water; but I merely mention the fact as undoubted, that with us where we have soft water the disease does not originate or prevail, and that in the islands where they have hard water it does prevail.

Will you describe any observations you may have made on the use or choice of soft water by cattle?—I have observed that horses, mules, and cattle, decidedly prefer rain-water to all other water.

Did you ever practise Dr. Clarke's process for softening water?—Yes. I happened to arrive in the colony during a period of protracted drought, when rain-water was very scarce, and the tanks nearly exhausted. I was led by this circumstance to examine the Artesian water, of which there is a considerable supply from various borings in Georgetown, and other places in the colony. I found its principal impurity to be bicarbonate of iron, and saw at a glance that Dr. Clarke's process of purification was applicable to it. I wrote to him mentioning the circumstance, and was empowered to use his process. Owing to the weather, no opportunity occurred for using it on the large scale for a considerable time; at length, however, a dry season limited the engineer of the Demerara Railway Company to the use of bush-water and Artesian-water for the use of the locomotives. Both these waters gave much trouble from causing the engines to *prime*, and also by reason of the deposit that took place within the boilers. I was then applied to by the Directors, and had an opportunity of applying Clarke's process to the Artesian-water.

Dr. Shier.

How did you find it answer?—Admirably. Preparations were made under my directions for the use of the process on a large scale; and the purified water, which answered perfectly, continued to be used so long as the drought lasted. The process was so satisfactory, and the necessary arrangements so simple and inexpensive, that I am satisfied that when a protracted drought again occurs in the colony, Clarke's process will be used for purifying Artesian-water for the use of the poorer classes, who have no means of keeping supplies of rain-water.

Then when the rain came, the rain was preferred?—Of course it was.

There was sufficient discrimination to prefer the water of one degree, or rain-water, to the water of four degrees of hardness?—Certainly; they would not have drunk the one, whilst they could get the other, even if the water of four degrees had been of the same temperature.

Have you any information regarding the action of Demerara rain-water on lead?—Yes. My attention was first called to the subject by Dr. Blair, our Colonial Surgeon-General, in consequence of symptoms of lead-poisoning occurring in his practice. On investigation, I found lead in the suspected water, and in quantity too large to admit of a doubt of its being the cause of great and wide-spread mischief. In one case, where I operated on the water contained in a lead-cistern in a dwelling-house, I obtained as much lead, as when reduced to the metallic state, formed a globule as large as a buck-shot. In all the cases examined, the lead was in the state of an insoluble hydrate, separable by a paper, felt, or sand-filter, as in the case of Dr. Clarke's case of the water at Lord Aberdeen's marine villa. A case of *colica pictonum* occurred last year in the Colonial Laboratory, from the use of rain-water from a lead-cistern and lead service-pipes. I have no doubt that most, if not all, the cases of this disease,—and it is of too frequent occurrence in the colony,—arise from the action of the rain-water on lead. I may add, that the recent rain-water generally contains a good deal of free carbonic acid.

When you were at Aberdeen, did you hear of any lead-poisoning, or injury from the use of soft water there?—No, I do not remember any, certainly.

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GENERAL BOARD OF HEALTH.

REPORT

ON THE

SUPPLY OF WATER

TO

THE METROPOLIS.

APPENDIX No. IV.

THE CESSPOOL SYSTEM IN PARIS.

Presented to both Houses of Parliament by Command of Her Majesty.

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1850.

REPORT

ON

THE CESSPOOL SYSTEM IN PARIS,

By Thomas W. Rammell, Esq., C.E.

The following account of the system adopted in Paris for the disposal of the refuse matter of the inhabitants was drawn up after some inquiries on the subject made during a visit to that city in the months of April and May 1848. Mr. Rammell.

These inquiries were only incidentally undertaken, at the request of the Metropolitan Sanitary Commissioners; and from circumstances were necessarily of a somewhat general character, and directed chiefly to the more prominent features of the subject: the account, therefore, cannot pretend either to great minuteness of detail, or fulness of exposition. Through letters of introduction, however, obligingly furnished by Mr. Chadwick, and the kind intervention of Mr. J. F. Clark, of the English Embassy, access was obtained to authentic sources of information, from which the writer was enabled to collect some important facts. These, it is hoped, being new, or not generally known in this country, will impart to the paper a degree of interest.

It is the practice in Paris to dispose of all the kitchen and dry refuse by depositing it in the streets at midnight, whence it is removed at dawn and during the early morning hours by the scavengers. In the meantime, however, the heaps are carefully turned over by the *chiffoniers*, a numerous class, to whom all sorts of odds and ends, such as bones, bits of bread, rags, old pots, broken bottles, &c., &c., have a marketable value.

The greater portion of the liquid refuse, including water which has been used in culinary or cleansing processes, is got rid of by means of open channels laid across the court-yards and the foot pavements to the street gutters, along which it flows until it falls through the nearest gully into the sewers, and ultimately into the Seine. If produced in the upper part of a house, this description of refuse is first poured into an external shoot branching out of the rainwater pipe, with one of which every floor is usually provided. Iron pipes have been lately much introduced in place of the open channels across the foot pavements; these are laid level with the surface, and are cast with an open slit about one inch in width at the top to afford facility for cleansing them. During the busy parts of the day there are constant streams of such fluids running through most of the streets of Paris, the smell arising from which is by no means agreeable. In hot weather it is the practice to turn on the public stand-pipes for an hour or two to dilute the matter and accelerate its flow.

With respect to fæcal refuse, and much of the house slops, particularly those of bed-chambers, the cesspool is universally adopted in Paris as the immediate receptacle. The cesspools are of two sorts: 1. Fixed or excavated cesspools; 2. Moveable cesspools.

In early times the excavated cesspools or pits, were constructed in the rudest manner, and cleaned out more or less frequently, or utterly

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neglected at the discretion of their owners. As the city increased in size, however, and as the permeations necessarily taking place into the soil accumulated in the lapse of centuries, the evil resulting was found to be of grave magnitude, calling for prompt and vigorous interference on the part of the authorities. It appears certain that prior to the year 1819, (when a strict *ordonnance* was issued on the subject,) the cesspools were very carelessly constructed. For the most part they were far from water-tight, and very probably were generally intended to be so. Consequently, nearly the whole of the fluid matter passed into them drained into the springs beneath the substratum, or became absorbed by the surrounding soil. Not only this, the basement walls of the houses became saturated with these offensive permeations, and the atmosphere, more particularly in the interior of the dwellings, tainted with their exhalations.

The moveable cesspools, for the most part, consist simply of tanks or barrels, which, when full, are removed to some convenient spot for the purpose of their contents being discharged. This form of cesspool, though not leading to the contamination of the soil naturally induced by the fixed or excavated cesspool, may occasion many offensive nuisances from carelessness in overfilling, or in the process of emptying.

It was with a view to protect the public health from the serious evils engendered by a reckless process of accumulation of fæcal matter that the *ordonnance* above referred to was issued on the 24th of September, 1819, laying down stringent regulations both as to the structure of cesspools fixed and moveable, and their mode of emptying. The execution of this *ordonnance* is entrusted to the Prefect of Police. The system established by it is evidently the fruit of a very careful study of the subject in all its details; and the regulations being very rigidly enforced, the cesspool system as carried out in Paris may be considered to be as perfect as the nature of the case will admit of. A description of it, therefore, however general, at the present time when public attention is so earnestly directed to everything that relates to the condition of our dwellings, may possibly not be entirely without value as a contribution to the stock of knowledge already collected on sanitary matters.

In the description which follows I propose to treat the subject under three principal heads, viz. :—

1. The construction of cesspools, fixed and moveable;
2. The modes of emptying them;
3. The places of deposit for the matter withdrawn; and the process of conversion of the soil into *poudrette*, by which it is fitted for uses to which it is ultimately applied;

And, in a concluding division, I shall consider the inconveniences which are found to be inseparably connected with the system even under the most perfect arrangements, and draw a comparison between the expense attaching to it and that which a system of tubular drainage would involve.

Construction of Cesspools.

1. *Fixed or Excavated Cesspools.*—The following are the principal provisions of the *ordonnance* of 1819, relating to the construction of the fixed or excavated cesspools; and as one of the articles ordained that "all cesspools existing at the date of this *ordonnance* shall be altered

in accordance with its provisions after the first subsequent emptying, or if that be found impracticable, shall be filled up;" the formulary so established, may be considered to represent the actual structure of all such cesspools in Paris. Mr. Rammell.

"The walls, the arch, and the bottom of the cesspool, shall be entirely constructed in '*pierres meulières*' (an exceedingly hard kind of stone), set in mortar, composed of hydraulic lime and clean river sand.

"The interior shall be plastered with mortar, made of the same materials.

"The arches shall not be less than from 12 to 14 inches (30 to 35 centimètres) in thickness, and the walls not less than from 18 to 20 inches (45 to 50 centimètres). The bottom shall be in the form of a basin, and the arch semicircular, or not varying from that form more than one third of the radius.

"All the angles of the interior shall be rounded to an arc whose radius shall not be less than 10 inches (25 centimètres). (The object of this regulation was to prevent the free evolution of gases, which acute angles had been found to favour.)

"The cesspools shall be on the plan, circular, elliptical, or rectangular, wherever the localities will allow the adoption of either of these forms. Acute angular forms will not be permitted, unless the area of the cesspool shall be at least 4 square mètres on each side of the angle, and then two man-holes shall be formed.

"No cesspool shall have a less interior height than 6 feet 6 inches (2 mètres) in the clear.

"The man-hole shall be placed near the middle; it shall not be less than 3 feet 3 inches long, by 2 feet 1½ inches wide (1 mètre by 65 centimètres), and its depth to the crown of the arch ought not to be more than 4 feet 10½ inches (1 mètre 50 centimètres). If the depth exceed this, the size of the opening must be increased in proportion.

"In addition to the man-hole, a hole, having a moveable stone cover, 1 foot 7½ inches (50 centimètres) in diameter, with an iron ring in its centre, shall be formed in that part of the arch furthest from the soil-pipe, unless the man-hole opens on a ground floor having an untrapped closet.

"The soil-pipe shall always be placed in the middle; its interior diameter shall not be less than 9⅞ inches (25 centimètres) if in pottery ware, and 7⅞ inches (20 centimètres) if in cast iron. A vent-pipe, not less than 9⅞ inches (25 centimètres) in diameter, shall be carried up to the level of the top of the chimneys of the house, or the chimneys of the adjoining houses, and neither of these pipes shall project into the cesspool beyond the line of the arch.

"When the cesspools are placed beneath cellars, such cellars must have a direct communication with the external air, and be large enough to contain four workmen with their tools, and they must be at least 6 feet 6 inches (2 mètres) high in the clear.

"No compartments or divisions shall be made nor detached pillars formed in the cesspools."

These provisions seem to embrace every point essential to the good construction of the cesspools: the form of this receptacle; the thickness of its walls and arches; the materials to be used in building it; the means of access to it; its ventilation: these points have all been

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well and judiciously considered by the authorities; and as the result, a very much more substantial and costly structure has been deemed proper for the temporary reception of fæcal matters in Paris than that in common use for the same purpose in this country.

A principal object of the *ordonnance* was to ensure the cesspools being thenceforth made water-tight; so that further pollution of the substratum and springs might be prevented; and the provisions for its attainment have been very strictly enforced by the police. The present cesspools are, in fact, water-tight constructions, retaining the whole of the liquids passed into them until the same are withdrawn by artificial means. The advantage has its attendant inconveniences, and moreover has been dearly paid for; for independently of the cost of the alterations and the increased cost of making the cesspools in the outset—the liquids no longer draining away by natural permeation—the constant expense of emptying them has enormously increased. In the better class of houses, where water is more freely used, whereas the cesspool was formerly emptied every eighteen months or two years, the operation has now to be repeated every three, four, or five months. An increased water supply has added to the evil; moderate even now as the extent of this supply is. Were the consumption equal to the demands of the English water-closet system, the expense and inconvenience would be increased to an intolerable degree.

The Parisian *cabinet* is not of a very perfect kind. The apparatus in common use consists of an earthenware basin communicating directly, or by a short branch, with the main soil pipe; the orifice being closed by a pan forming a very imperfect trap. In the inferior class of houses, the orifice of the basin is generally untrapped. Water is poured in from a pitcher in sufficient quantity to prevent complete obstruction; and to preserve a very moderate degree of cleanliness, the action of the liquid being occasionally assisted by the use of a long stick and a short stumpy broom, articles to be seen in almost every *cabinet*. The expense and labour of fetching the water, and the desire to avoid frequent emptyings of the cesspool, prevent its very copious use.

In the better description of houses there is usually at least one *cabinet* upon every floor, those of modern construction having one to every set of apartments. In houses of the inferior class, three, two, and sometimes one only, serve the wants of the whole of the inmates.

The section below exhibits the usual form of an excavated cesspool:—

The apparatus A B C is sometimes fixed in the cesspools to facilitate the process of extracting their contents. It consists of a pipe, generally of lead, B, about 4 inches (10 centimètres) in diameter, having a screw-cap, A,—by removing which the suction pipe of a pump may be connected,—and a small grated well, C, of cast iron to prevent the entrance of larger substances than will pass freely through the pipe. With this apparatus a cesspool may be emptied of everything, excepting large foreign substances, without opening the man-hole. A police regulation, however, directs that every time a cesspool is emptied it shall be opened for the purpose of ascertaining its state of repair, and this prevents any general adoption of the apparatus, as the only benefit now derived from it is the postponement of the operation of opening the cesspool until after the greater part of its contents have been withdrawn.

The usual capacity of the cesspools is from 10 to 12 cubic yards

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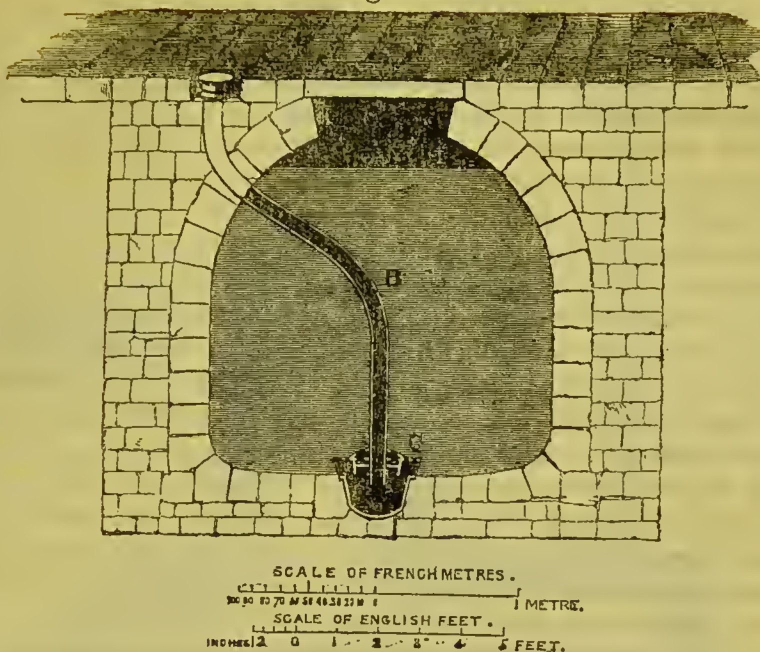
Fig. 1.



(8 to 10 cubic mètres), and the cost of one, built in accordance with the ordonnance, and of the usual size, cannot be estimated at less than 18*l.* sterling.

A house in Paris has frequently two or three of these cesspools, affording together space for the temporary reception of from 20 to 30 cubic yards of night-soil, placed, to suit local convenience, in different parts of the premises, sometimes under the house itself, sometimes under the courtyard. It must be borne in mind, however, that the houses in Paris are generally much larger than in London, so much so, indeed, that a single floor there may, without much exaggeration, be compared to an entire house here, it generally presenting sufficient accommodation for at least one family. Houses containing accommodation for 60 or 70 individuals are by no means rare, and the average number of inmates is very high; exceeding 24, according to the census of 1817.

This arrangement of the habitations has some bearing upon the question of drainage, for the communication between the several floors being vertical, not horizontal as between the houses here,—the solid matter produced on each can be passed with great facility, and with the aid of only a very small quantity of water, through a main soil-pipe, into one or more receptacles common to all. A certain amount of economy is the result.

The average degree of fluidity of the matter found in the excavated cesspools is what would be produced by the mixture of about one solid part with four of liquid; the solid (with the exception of foreign substances) consisting entirely of fæcal matter; and the liquid being composed of about three parts urine to five of water. It is estimated that, in the better class of houses, the daily quantity of matter, including the water necessary for cleanliness and to ensure the passage of the solids through the soil-pipe, passing into the cesspool from each individual amounts to 1¾ litres (3·08 English pints). Foreign substances are

Mr. Rammell. — found in great abundance in the cesspools; the large soil-pipes permitting their easy introduction; so that the cesspool becomes the common receptacle for a great variety of articles that it is desired secretly to get rid of. Article 19 of the Police Regulations directs that nightmen finding any articles in the cesspools, especially such as lead to the suspicion of a crime or misdemeanor, shall make a declaration of the fact the same day to a Commissary of Police.

The cesspools vary considerably in foulness; and it is remarkable that those containing the greatest proportion of water are the most foul and dangerous. This is accounted for by the increased quantity of sulphuretted hydrogen gas evolved: and is more particularly the case where, from their large size, or from the small number of people using them, much time is allowed for the matter to stagnate and decompose in them. Soap-suds are said to add materially to their offensive and dangerous condition. The foulness of the cesspools, therefore, would appear to be in direct proportion to the cleanly habits of the inmates of the houses to which they respectively belong. Where urine predominates ammoniacal vapours are given off in considerable quantities, and although these affect the eyes of those exposed to them, and the nightmen suffer much from inflammation of these organs, no danger to life results. The inflammation, however, is often sufficiently acute to produce temporary blindness, and from this cause the men are at times thrown out of work for days together.

2. *Moveable Cesspools.*—There are two sorts of moveable cesspools; the one extremely simple and primitive in construction, the other more complicated. The former retains all the refuse, both liquid and solid, passed into it; the latter retains only the solid matter, the liquid being separated by a sort of strainer, and running off into another receptacle.

The advantage of this separating apparatus is that those cesspools provided with it require to be emptied less frequently than the others; the solid matter being alone retained in the moveable part. The liquid portion is withdrawn from the tank in which it is received by pumping.

In the following illustration, Fig. 2 exhibits one of these cesspools, as it is usually fixed in the cellar or basement of a house, and Fig. 3 a section of the strainer or separating apparatus.

In Fig. 2, A is the moveable receptacle retaining the solid portion only of the matter which falls into it through the soil-pipe B. Its usual capacity is 55 gallons (250 litres). C is a loose muff of galvanized iron, connecting the soil-pipe with the dividing apparatus. D is a fixed tank or reservoir, constructed either of oak lined with lead or of rubble stone set in mortar, composed of hydraulic lime and clean river sand, and having its interior lined with Roman cement (sometimes a former cesspool is used for this reservoir). E is a man-hole. The capacity of this reservoir is generally about 880 gallons (4,000 litres).

Fig. 3 is a vertical section of the separating apparatus; it consists of two cylinders of zinc, differing in diameter about three centimètres, one fixed within the other. The surface of the inner cylinder is pierced with numerous small holes, so that it acts as a strainer, retaining the solid matter, and allowing the fluid to fall to the bottom of the outer cylinder, whence it is conducted by the pipe F into the reservoir D.

When the receptacle A is full, it is detached and removed in the following manner:

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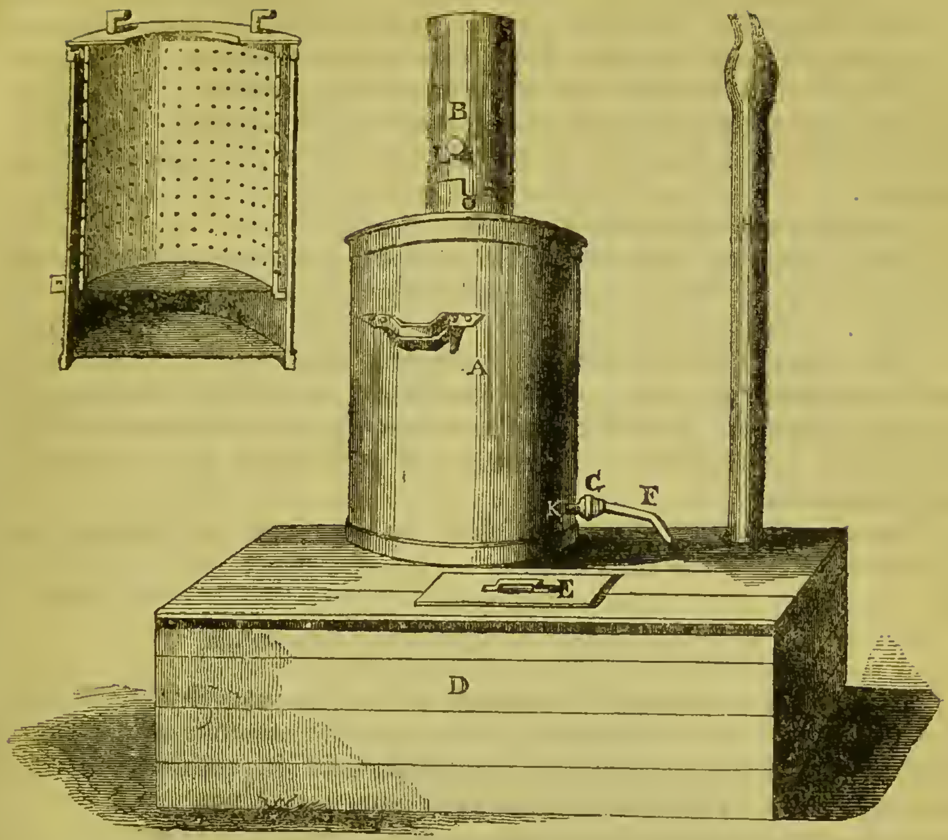
Fig. 3. Fig. 2.



The collar G is first unscrewed, the tube F detached, and a plug screwed into the socket K; the loose muff C is then lifted on to the pin L, a cover fitted into the opening in the top of the cylinder, and the receptacle A carried into a cart by a couple of men, an empty one being immediately substituted in its place.

The liquid matter contained in the reservoir D is removed by pumping into closed carts; the suction-pipe being attached to the fixed leaden pipe H, which, if the apparatus is placed in a cellar, is usually carried up into the yard. The pumps ordinarily used are worked by two men, and will fill a cart of the capacity of 2,000 litres in about 15 minutes.

The other kind of moveable cesspool consists simply of a wooden cask, set on end, and having its top pierced to admit the soil-pipe, which is connected in the manner before described. It is intended to retain both solid and liquid matter. When full, it is detached as in the former case, and the aperture in the top having been closed by a tight-fitting lid secured by an iron bar placed across, it is removed, and an empty one immediately substituted for it.

The moveable cesspool last described is much more generally used than the other kind; very few are furnished with the separating apparatus. But the use of either sort, I am told, is not on the increase. They are found, on the whole, to be more expensive than fixed cesspools, besides entailing many inconveniences, one of which is the frequent entrance of workmen upon the premises, for the purpose of removing them, which sometimes has to be done every second or third day. Moreover, if the

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cask becomes in the slightest degree overcharged, there is an overflow of matter when the soil-pipe is detached. On the other hand, if the removal takes place before the cask is completely filled, there is a waste of expense. Indeed the moveable system seems to be now only adopted where some difficulty had been found in altering the then existing fixed cesspools, in accordance with the *ordonnance* of the 24th September, 1819, or where it has been an object to avoid the first cost of a fixed cesspool.

The police regulations declare that—

"No apparatus of a moveable cesspool not approved of by the authorities shall be established in Paris for replacing cesspools in masonry.

"No apparatus of a moveable cesspool shall be fixed, without a previous declaration made at the prefecture of police by the owner, or by the contractor. A plan of the localities where the apparatus is to be placed, and a description of the means of ventilation shall be added to this declaration.

"Every apparatus when full shall be removed and replaced by another before the soil runs over."

II. The Mode of Emptying Cesspools.

The mode of emptying the cesspools is the next branch of the subject, and one which has exercised a good deal of ingenuity on the part of those who make a commercial speculation of it, besides constantly demanding the vigilant attention of the police authorities.

With regard to the moveable cesspool, the process of emptying is very simple, though undoubtedly demanding a considerable expenditure of labour. The tank or barrel, when filled, is, as before stated, disconnected from the soil-pipe, an empty one being immediately substituted in its place, and the bunghole being securely closed, it is conveyed away on a vehicle, somewhat resembling a brewer's dray (which holds about eight or ten of them), to the spot appointed as a depository of its discharged contents.

The removal of moveable cesspools is allowed to take place during the day.

Fixed or excavated cesspools, of course, require to be emptied on the spot into carts, which for the time answer the duty of moveable cesspools, insofar as relates to the purpose of transport. The process is necessarily attended, more or less, with stench and other disagreeable incidents to the annoyance of the inhabitants of the neighbourhood, and the passers by; and the police regulations, therefore, whilst providing every precaution which prudence could suggest as to the mode in which the process is conducted, require further that no cesspool shall be emptied, and no soil-cart employed in emptying it shall be allowed to go through the streets of Paris between the hours of eight in the morning and 10 in the evening from the 1st of October to the 31st of March; nor between the hours of six in the morning and 11 in the evening from the 1st of April to the 30th of September.

The proprietors of houses are required to empty their cesspools so soon as they are full, having previously given notice by a declaration in writing of their intention to do so. No cesspool may be partially

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emptied without authority from the police. The soil must be thoroughly cleaned out, and then the cesspool swept and washed before it is again closed. No cesspool may be closed, after being emptied, without a written authority given, after inspection, by the Director of Public Health, or by the Commissary, architect of the *Petite Voirie.*

The repairing of a cesspool is to be notified and performed with the same formalities and precautions as the emptying of one.

Before opening any cesspool, whether for the purpose of emptying or repair, precautions are taken to prevent accidents which might be produced by the escape or ignition of the gases which may have generated in them. The police regulations provide that no person shall be allowed to follow the business of nightman without having previously obtained a license or permission from the prefect of police, which is only granted after proof that the party is provided with the necessary apparatus, and carts for the extraction and transport of the soil, and also, with a suitable establishment or depôt in a certain locality, for their reception when not in use. The stock of the contractors for emptying night-soil is inspected at least twice a-year, when, if found inadequate, or out of repair, his license is withdrawn.

Other regulations provide that not less than four men shall form the "gang" employed in every case; that the soil shall not be removed from the cesspool until the carts have arrived; and that the carts, or apparatus, filled with night-soil, shall be removed direct to the depôts specified by the public authorities for its deposit.

Vidange Companies.—There are several companies in Paris—in all I believe eight—which undertake the extraction and removal of the contents of cesspools; they are termed *Compagnies de Vidanges.* That known as the *Compagnie Richer* is the most important of them, doing more than half the entire work. The capital invested in the working stock of this Company is, as I am informed, upwards of 200,000*l.* sterling. Their *service* requires, at the present rate of business, the labour of 350 horses, and the use of 120 vehicles of various descriptions. Their principal establishment is at Montfaucon, adjoining the *Voirie*, the spot upon which the night-soil of Paris has for ages been deposited. M. Heloin, the Managing Director of this Company, with much courtesy, gave me full explanations as to their mode of working; and as it does not differ in any material particular from that generally pursued, I shall confine myself, in the following details, to what I observed, or was informed of, in this establishment.

The mode of emptying the excavated or fixed cesspools adopted by this Company, and, indeed, universally in Paris, is to pump their contents into closed carts for transport. This operation is performed with two descriptions of pumps, one working on what may be called the hydraulic principle, the other on the pneumatic. In the former the valves are placed in the pipe communicating between the cesspool and the cart, and the matter itself is pumped. In the latter the valves are placed beyond the cart and the air being pumped out of the cart, the matter flows into it to fill up the vacuum so occasioned. The real principle is of course the same in both cases, the matter being forced up by atmospheric pressure. One advantage of the pneumatic system is, that there are no valves to impede the free passage of matter through the

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suction pipe; another, that it permits the use of a pipe of larger diameter.

The cart employed for the pneumatic system consists of an iron cylinder, mounted sometimes upon four, but generally upon two wheels, the latter arrangement being found to be the more convenient. Previous to use at the cesspool, the carts are drawn to a branch establishment, situated just within the Barrière du Combat, where they are exhausted of air with an air-pump worked by steam power. A 12-horse engine erected here is capable of exhausting five carts at the same time; the vacuum produced being equal to $28\frac{3}{8}$ inches (72 centimètres) of mercury. A cart in good repair, and upon two wheels, will preserve a practical vacuum for 48 hours after exhaustion.

The usual capacity of both descriptions of cart is 2,000 litres, the largest size allowed by the police regulations, and the total weight, when full, about 3 tons 8 cwt. Three horses are employed to draw it.

Fig. 3.

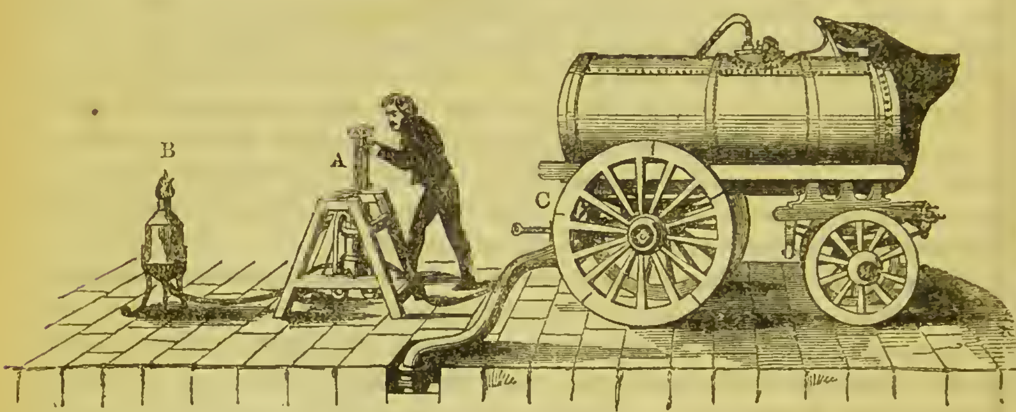


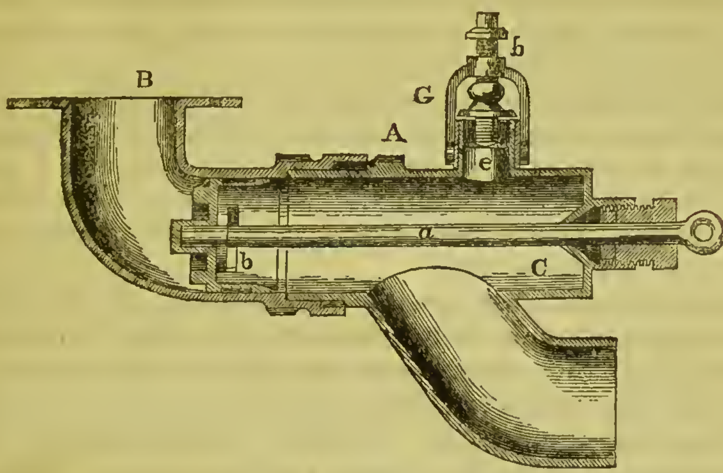
Fig. 3 represents one of the carts mounted upon four wheels, used for the pneumatic system, with a small air-pump for completing the exhaustion at the scene of operations shown at A, and a furnace for burning the foul air withdrawn, shown at B. The body of the cart is cylindrical, and is made of plates of wrought iron rivetted together.

The suction-pipe from the cesspool is connected by means of the piece C, which not only serves as the apperture for filling the cart, but also as the apperture for discharging its contents. It is shown on an enlarged scale in the drawing below, fig. 4, connected with the curved pipe B, which is usually fixed underneath the cart, near the end of the cylinder; sometimes this pipe is made to project horizontally from the end. The communication with the suction pipe, or the external air, is opened or closed by the plug *b*, which may be withdrawn from or inserted into the aperture by the rod *a*.

In order to save expense it was attempted to substitute wood for the iron used for the body of the cart, A very straight-grained wood was selected for the purpose, and subjected to some preparation. After the cylinder was formed, it was coated and lined with a composition, of which pitch was a principal ingredient. The attempt, however, was not successful, for, in use, it was found that the vacuum could not be maintained in these carts with certainty, in consequence

of the expansion and contraction of the material under the influence of atmospheric changes. — Mr. Rammell.

Fig. 4.



The body of the cart used for the hydraulic system is formed of wood, strongly bound with iron hoops; and in shape resembles a butt. It holds, as the others, 2,000 litres, and is usually mounted, without springs, upon two wheels. The delivery pipe from the pump communicates at the top. The contents are discharged at the lower part behind.

The number of carts required for each operation, of course, varies according to the size of the cesspool to be emptied; but as these contain on the average about five cart-loads, that is the number usually sent.

In addition to the carts for the transport of the night-soil, a light-covered spring van drawn by one horse is used to carry the tools, &c. required in the process.

These consist of—

1. An air-pump when the work is to be done on the pneumatic system, and of a hydraulic pump when it is to be done on the hydraulic system.
2. About 50 mètres of suction-pipe of various forms and lengths.
3. A furnace for the purpose of burning the gases.
4. Wooden hods for the removal of the solid night-soil.
5. Pails, a ladder, pincers, levers, hammers, and other articles.

I shall now endeavour to describe the operation of filling the carts as performed upon the pneumatic system, with the machines and implements used for the purpose.

The carts belonging to the Compagnie Richer, are first taken to the establishment near the Barrière du Combat, where, as before stated, they are exhausted of air by steam power.

An opening into the cesspool having been effected, the suction-pipe is laid from this receptacle to the cart. This pipe is $3\frac{15}{16}$ inches (10 centimètres) in diameter, and is in separate pieces of about 10 feet each, with others shorter (down even to 1 foot), to make up any exact length required. Two kinds of it are commonly used; one made of leather, having iron wire wound spirally inside to prevent collapse, the other of copper.

The leather pipe is used where a certain degree of pliability is required; the copper for the straight parts of the line and for determined curves; pieces struck from various radii being made for the purpose.

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Other materials have been employed for the pipe. Gutta percha was tried as a substitute for leather, but the pipes of this material were found to be liable to splitting. Lately a wrought-iron coated with lead by a new process has been tried, and it is thought may replace the copper. This description of pipe, however, has not yet had a sufficiently long trial to test its merits.

To prevent choking from the entrance of foreign substances, the end of the pipe placed in the cesspool is on the hydraulic system, usually protected by an enlarged piece, about 1 foot long and 9 inches in diameter, made of wrought-iron, and pierced with holes, but on the pneumatic system, where there are no valves in the suction pipe, this contrivance is very rarely used.

The communication between the suction-pipe and the cart being opened by withdrawing, as before described, the plug *b* by means of the forked rod *a* into the recess *c*,—an operation requiring the strength of two men—the matter in the cesspool immediately rushes into the cart, being forced up by the weight of the atmosphere, with considerable velocity to occupy the vacuum existing, which it will do entirely in from two to three minutes. The cart will then be about three-fourths filled with matter, the remaining space being occupied by the rarefied air previously existing in the cart, and by the air contained in the length of suction-pipe. The operation is completed, and the cart entirely filled, by withdrawing this air with a small air pump usually worked by two men. (See Fig. 3.) This is placed upon the ground, and communicates with the cart at top, by a flexible India-rubber tube, about 1 inch in diameter; the air, as fast as it is pumped out, being forced through a similar tube, communicating underneath with the furnace B, where it is burnt. For ascertaining when the cart is full, a piece of glass tube is inserted in the brass end of the air-pipe, through which, by the aid of a small lartern placed near, the matter may be seen to rise.

In case the suction-pipe should become choked, it is cleared by the contrivance shown at G, figure 4. The plug *b* having been thrust back into its place, the piece *d* is unscrewed and turned down; a communication is then opened with the atmosphere through *e* by lifting the valve *f* when its pressure causes the matter contained in the pipe rapidly to descend.

The valve *f* may now be again closed and secured by the piece *d*, the plug *b* again withdrawn, and the operation of filling continued.

When a cart is completely filled, the air-pipe and suction-pipe are detached, and the orifices closed. It is then drawn away, another being immediately brought up to undergo the same process.

In the hydraulic system the suction-pipe used formerly was only $2\frac{1}{6}$ inches ($5\frac{1}{2}$ centimètres) in diameter, but the *Compagnie Richer*, by the use of a peculiar pump, which they have patented, have been enabled to increase theirs to nearly $3\frac{1}{6}$ inches (8 centimètres) in diameter.

The peculiarity of the pump adopted by the Compagnie Richer consists in the use of what may be called leathern lungs to perform the function of the cylinder and pistons in common use; in other respects it is an ordinary double-force pump. By this improvement a considerable amount of friction and consequent labour is saved. These pumps rarely get out

of order; and they are easily repaired, no very accurate fitting of the parts being required. Mr. Rammell.

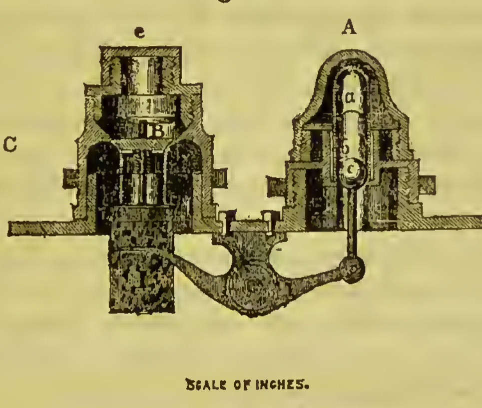
The hydraulic pump is usually worked by four men; it is placed upon the ground at the most convenient spot, and the cart may be filled, under ordinary circumstances, in from three to five minutes.

The furnace consists of a sheet-iron cylinder, about 9 inches in diameter, pierced with small holes, and covered with a conical cap to prevent the flame spreading. The vent-pipe first communicates underneath with a small reservoir, intended to contain the matter in case the operation should be carried too far. A piece is inserted in the bottom of this reservoir, by unscrewing which it may be emptied.

The furnace is sometimes fixed upon a plank, which rests upon two projecting pieces behind the cart.

The indicator sometimes used is represented in Fig. 5. A glass tube *a* (which when not in use is protected by a copper cap) is fixed in the piece *b*; *c* is an indicator fixed on one end of the lever *l*, which rises and falls in this tube; upon the other end of this lever is a cork float, L; when the cart is nearly full, the cork from L rising causes the indicator *c* to descend; this is seen through the glass tube, a small lantern being placed near it.

Fig. 5.



Several contrivances to give the workmen notice of the completion of the operation of filling the cart being near at hand, have been tried. A float rising and stopping the mouth of the air-pipe communicating with the furnace was tried. On the first occasion it answered very well, the pump being suddenly brought to a stand-still. On the second occasion the men continued pumping, although the labour became exceedingly heavy; at last a violent explosion took place; the ends of the cart, with its contents, being forced out and blown to a considerable distance. The noise was so loud that a detachment of men was despatched from the nearest *Corps-de-Garde*, on the supposition that an explosion of gunpowder had taken place. Upon examination it was found, that on the former occasion the float had been pressed so tightly against the orifice of the air-pipe as to prevent its subsequent descent, and consequently no escape of air could take place on the second trial.

Towards the end of the operation, when the quantity of matter remaining in the cesspool, although sufficiently fluid, is too shallow for pumping, it is scooped into a large pail; and the end of the suction-

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pipe being introduced, drawn up into the cart. When the matter is in too solid a state to pass through the pipe, it is carried to the cart in hods, unless it is in considerable quantity. In that case it is removed in vessels called "*tinettes*," in the shape of a truncated cone, holding each about 3½ cubic feet. These vessels are closed with a lid, and are lifted into an open waggon for transport.

The greatest length of suction-pipe that can be worked on the pneumatic system is about 100 mètres; but this will of course vary according to the greater or less depth of the cesspool, and the fluidity of the matter to be pumped. The greatest depth that can be worked with a short length of pipe at the vacuum used is about 26 feet.

On the hydraulic system I am told that practically there is no limit to the length of pipe, and, of course, there is none to the depth. A length of 200 or 300 yards can be worked without greatly increased labour.

The friction through the pipe cannot be regarded as adding much to the labour of pumping when the slowness of the motion is taken into account; at least, supposing the matter to possess a tolerable degree of fluidity, and the machine to be double acting.

The quantity of soil that a gang will remove during the night varies from 18 to 60 cubic mètres, according to the size and depth of the cesspool, the fluidity of the matter, the distance to be gone over, &c. Every gang is expected to perform at least 18 cubic mètres. All done beyond that quantity is paid for extra.

In fixing the rate of charge to the proprietors of houses, Paris has been divided into three districts, by concentric arcs drawn from the *Voirie* of Montfaucon as a centre. In the district nearest to the *Voirie* the charge is 8 francs per cubic mètre; in the others, 9 and 10 francs respectively; this includes every expense, excepting when the deodorizing fluid is used, which it very rarely is; for that an extra charge of 60 centimes, about 6*d*. per cubic mètre, is made. The charge to the proprietors is the same whether the work is performed on the pneumatic or the hydraulic system.

The pneumatic system was introduced only about four or five years since, and the Company Richer went to very considerable expense in carts and machines for carrying it out in a very perfect manner, and upon an extensive scale; conceiving that it offered advantages in permitting the use of a much larger suction-pipe, and the abolition of the valves within it. These advantages, however, have a good deal diminished in value since the adoption of the improved pump for the hydraulic system, which has also permitted an increase in the size of the suction-pipe, and that to an extent more than double its former sectional area.

Independently of the expense of producing the vacuum by steam-power, and which in Paris where coal is dear is by no means inconsiderable, the working expenses of the pneumatic system are nearly if not quite as heavy as those appertaining to the hydraulic system. There is little or no saving in the number of men at the cesspool—a police regulation requiring that there shall never be less than four present in case of accident. And even if such a regulation did not exist, no great saving in this respect could be effected, as a pump requiring the labour of two men, and inconveniently placed near the cart, and as far as possible from the cesspool, has still to be worked at the close of the operation.

Moreover, the carts employed for this system are much more costly than those used for the hydraulic system. Iron has to be substituted for wood for the body, and very accurate workmanship and fitting of every separate piece is required to ensure the certain action of the principle. It is absolutely necessary, too, that the carts should be kept in perfect repair. To guard against the effects of jolting upon rough pavement, they were at first mounted upon springs, which from the heavy weight thrown upon them, were constantly requiring repair. Mr. Rammell.

Taking into account the interest on additional capital sunk in the first cost of the machines, the increased expense of repairs, and some slight increase in the working expenses, it is estimated that the pneumatic system is the more expensive of the two by at least 25 per cent.

Looking at this fact, in connexion with the increased efficiency of the hydraulic system, it is not unreasonable to conclude that the pneumatic system will not long maintain the ground it has gained, but will yield it up again to the hydraulic system which it has to some extent displaced.

Complicated, laborious, and expensive as the operations above described are, it must not be supposed that the process of emptying a fixed cesspool is no longer a nuisance. The magnitude of the original evil is certainly much diminished by the improved method adopted; but in its reduced dimensions it still exists, and will continue to exist as long as the cesspools themselves. On the first removal of the stone that covers the man-hole, there is an escape of gas from the cesspool, and this goes on in greater or smaller volume until this aperture is again closed up; during the pumping the matter oozes from the joints of the pipe if they are not perfectly tight, and from the pipe itself should there be a flaw in any of the lengths: there is an escape of it also on shifting the pipe from one cart to another, and when the several lengths of pipe are disconnected after the operation is completed.

Amongst the means adopted to prevent the vitiation of the atmosphere, is a furnace to burn the noxious gases evolved, and which is not only used for consuming the air drawn from the pneumatic carts at the spot where they are exhausted, but is also conveyed with the carts to every cesspool to be emptied. The advantages attributed to it, however, are very much overrated. When the pump is in full operation, the gases are forced through the furnace with a rapidity too great to allow of perfect combustion; and even supposing the combustion perfect, the resulting gas or smoke evolved and discharged into the atmosphere cannot fail itself to be of an offensive character.

From some or all of these causes there is sufficient gas escaping to vitiate to a greater or less extent the surrounding atmosphere, as I know from experience, having twice, after witnessing these operations, suffered from attacks of illness. On the first occasion the men engaged in the operation omitted to burn the foul air, and the atmosphere being at the time excessively charged with moisture, owing to a heavy fall of rain which had taken place during the evening, so intense was the odour given off, that although the house to which the cesspool belonged was situated in the Rue du Port Mahon, and a perfect calm prevailed, it was most disagreeably perceptible as far off as the Rue Menars, a distance of more than 400 yards. I reached the scene of operation a little after 12 o'clock, and remaining only a few

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minutes, returned home and retired to rest. About 2 o'clock I awoke with a sensation of sickness, and was shortly afterwards taken with violent vomiting and diarrhœa; symptoms which continued at intervals during the greater part of the night, accompanied with alternate fits of shivering and feverish flushing, and also with intense pain across the forehead. In the morning I found my muscular strength completely prostrated, and I did not entirely recover it for a week or ten days afterwards. On the second occasion the attack was much more mild, and unaccompanied by vomiting.

III. Places of Deposit for the Matter withdrawn from the Cesspools.

The present produce of the cesspools of Paris amounts to between 600 and 700 cubic mètres a-day. The principal, and until a few years ago, the only, place of deposit for this matter was the *Voirie* of Montfaucon. M. Jules Garnier, in his "Visite à Montfaucon," says, "For more than nine centuries Montfaucon has been devoted to this purpose. It was there that the inhabitants of Paris were in the habit of depositing their filth before the walls of the capital extended beyond what is now the *Quartier Central.* The distance between Paris and Montfaucon was then more than half a league." At Montfaucon the solid portion of this matter is manufactured into a dry manure, called, from its peculiar appearance, *poudrette.* The basins belong to the *commune* of the city, who have been in the habit of farming them, together with their contents, for periods of nine years, to the highest bidder.

The produce of this sale has increased enormously of late.

			Francs.		Sterling per Annum.
In 1808	the sale was	effected for	97,000,	or about	£3,880
In 1817	,,	,,	75,000	,,	3,000
In 1834	,,	,,	165,000	,,	7,000
In 1843	,,	,,	525,000	,,	21,000

The proceeds are appropriated by the *commune.*

There appears, however, to be some disposition on the part of the proprietors of the houses to claim a property in the soil after it is deposited at the *Voirie,* and to the proceeds of the sale; and I have been informed that, at the next letting, it is probable they will take measures to try this question of right.

In addition to the manufacture of *poudrette,* a considerable quantity of ammonia is extracted from the liquids, about one-third of the whole being passed through some chemical works for the purpose. The right of extracting the ammonia is farmed at present for 3,200*l.* per annum: this farm-rent belongs to the *Fermier General.*

Voirie of Montfaucon, and Manufacture of Poudrette.—The *Voirie* of Montfaucon is situated to the north of Paris, at a short distance from the Barriers, and not far from the road to Meaux and the basin of La Villette—the feeder of the Canal de l'Ourcq. It is at a considerable elevation above the plain of Paris.

The site of the *Voirie* has undergone extensive excavations for gypsum, or plaster of Paris, and its surface is extremely uneven. The area, which is about 40 acres in extent, is divided into three irregular compartments:—1. The system of basins. 2. The ground used for

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spreading and drying the matter. 3. The place where the matter is heaped up after having been dried.

The basins, standing for the most part in gradations, one above another, by reason of the slope of the ground, are six in number. The two upper ones, which are upon a level, first receive the soil upon its arrival at the *Voirie;* the four others are receptacles for the more liquid portion as it gradually flows off from the upper basins.

The ground used for spreading and drying the matter is, in some places, flat; in others, more or less steep: the latter is most favourable for its easy distribution.

There is a great difference in the character of the soil brought; that taken from the upper part of the cesspools, and amounting to a large proportion of the whole, being entirely liquid; while the remainder is more or less solid, according to the depth at which it is taken. The whole, however, during winter or rainy weather, is indiscriminately deposited in the upper basins; but in dry weather, the nearly solid portion is at once thrown upon the drying ground.

It is in the upper basins that the first separation of the liquids and solids takes place; the latter falling to the bottom, and the former gradually flowing off through a sluice into the lower basins. This first separation, however, is by no means complete, a considerable deposit taking place in the lower basins. The mass in the upper basins, after three or four years, then appears like a thick mud, half liquid, half solid; it is of depth varying from 12 to 15 feet. In order entirely to get rid of the liquids, deep channels are now cut across the mass, by which they are drained off, when the deposit soon becomes sufficiently stiff to permit of its being dug out and spread upon the drying-ground, where, to assist the desiccation, it is turned over two or three times a-day by means of a harrow drawn by a horse.

The time necessary for the requisite desiccation varies a good deal, according to the season of the year, the temperature, and the dry or moist state of the atmosphere. Ere yet it is entirely deprived of humidity, the matter is collected into heaps, varying in size usually from 8 to 10 yards high, and from 60 or 80 yards long, by 25 or 30 yards wide. These heaps or mounds generally remain a twelvemonth untouched, sometimes even for two or three years; but as fast as the material is required, they are worked from one of the sides by means of pickaxes, shovels, and rakes; the pieces separated are then easily broken and reduced to powder, foreign substances being carefully excluded. This operation, which is the last the matter undergoes, is performed by women. The *poudrette* then appears like a mould of a grey-black colour, light, greasy to the touch, finely grained, and giving out a particular faint and nauseous odour.

The finer particles of matter carried by the liquids into the lower basins, and there more gradually deposited in combination with a precipitate from the urine, yield a variety of *poudrette*, preferred, by the farmers, for its superior fertilizing properties. In this case the drying process is conducted more slowly and with more difficulty than in the other, but more completely.

In general the *poudrette* is dried with great difficulty; it appears to have an extreme affinity for water; few substances give out moisture more slowly, or absorb it more greedily from the air.

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A good deal of heat is generated in the heaps of dessicated matter. This is always sensible to the touch, and sometimes results in spontaneous combustion.

The intensity of this heat is not in proportion to the elevation of temperature of the atmosphere. It is promoted by moisture. The only means of extinguishing the fire when it is once developed is to turn over the mass from top to bottom, in order to expose it to the air. Water thrown upon it, unless in very large quantities, would only increase its activity.

The quantity of *poudrette* sold in 1818 was—

At the *Voirie*	50,000 *setiers* (4¼ heaped bushels, each English measure.)
Sent into the departments .	20,000 *setiers.*
Total sale, 1818 . . .	70,000 *setiers*, at prices of 7, 8, 9 francs the *setier.*

This is equal, at the average price of 8 francs, to 22,400*l.* sterling.

The refuse liquids, as fast as they overflow the basins, or are passed through the chemical works, are conducted into the public sewers, and through them into the Seine, nearly opposite the Jardin des Plantes. They thus fall into the river at the very commencement of its course through Paris, and pollute its waters before they have reached the various works lower down, and near the centre of the city, where they are raised and distributed for household purposes, for the supply of baths, and for the public fountains.

Before quitting Montfaucon and its products, I may mention that a plot of ground adjoining the *Voirie* is set apart as a slaughtering-ground for horses, and as a place of deposit for the carcasses of all those dying in Paris. The late M. Parent du Chatelet, to whose Reports I am indebted for many of the preceding particulars, says, "According to the report of the women who skin them, it appears that the number of these carcasses is considerable, since they have sometimes received as many as 500 a-week. This, however, must probably be looked upon as an exceptional case, as in the numerous journeys I have made to the *Voirie*, I have never counted more than 15 or 20 taken in in the course of the day."

"The unburied carcasses of these animals would undoubtedly produce disease, were it not that, before decomposition can take place, they are devoured entirely by rats. These animals are found by thousands in this place, and their voracity is such, that I have often known them, during a single night, convert into skeletons the carcasses of 20 horses which had been brought the evening before. The bones are burnt to heat the coppers, or to get rid of them."

Speaking of the disgusting practices at the *Voirie*, Mr. Gisquet says, "I have seen men stark naked, passing entire days in the midst of the basins seeking for any objects of value they might contain. I have seen others fishing for the rotten fish the market inspectors had caused to be thrown into the basins. Two cartloads of spoilt and stinking mackerel were thrown into the largest of the basins; two hours afterwards all the fish had disappeared."

The emanations from the *Voirie* are, as may well be supposed, most

powerfully offensive. To a stranger unaccustomed to the atmosphere surrounding them, it would be almost impossible to make the tour of the basins without being more or less affected with a disposition to nausea. Large and numerous bubbles of gas are seen constantly and rapidly rising from a lake of urine and water, while evaporation of the most foul description is going on from many acres of surrounding ground upon which the solid matter is spread out to dry. Such is the state of fermentation of the liquids in the basins that their temperature is said to be considerably elevated. Mr. Rammell.

In perfectly calm weather these disgusting exhalations spread over a wide area around the *Voirie.* From habit the inhabitants of the neighbourhood may disregard them, but the stranger coming from Paris will perceive a disagreeable odour before or immediately after he has passed the Barrier. A fresh breeze will carry them over a distance of many miles, and when blowing from a northerly direction, the foul volume is swept by it entirely across Paris. Under peculiar states of the atmosphere its presence may be distinguished at the opposite extremity of the city; in the centre, and particularly along the quays, it is at such times most disgustingly apparent; while on the Boulevards, Bonne Nouvelle, St. Martin du Temple, &c., it prevails in intolerable strength; there it penetrates everywhere, pervading the cafés, the theatres, and the houses.

M. Parent du Chatelet thus describes the gigantic nuisance in a report to the Council of Health, written in 1833:—

"The influences of this *Voirie* have necessarily increased with the quantity of matter which has been deposited there. At the present time the infectious emanations given out from it are insupportable at all seasons within a circumference of 2,000 mètres (about 1¼ miles); and the winds carry them sometimes with all their intensity to a distance of 4,000 mètres, and evidence collected by the Commission charged to ascertain the extent of the ravages of the cholera in the rural communes, shows that certain states of the atmosphere, rarely occurring it is true, propagate them even to a distance of eight French miles (nearly five English miles). Can it be otherwise while the superficial area of the basins alone is 32,800 mètres (39,228 square yards), without including 12 acres occupied by the dry matter and the knackers' yard; and while from 230 to 240 cubic mètres of matter withdrawn from the cesspools are daily deposited there, and the larger part of the carcasses of 12,000 horses, and of from 25,000 to 30,000 small animals are allowed to rot upon the ground."

New Voirie at Bondy.—The nuisance was found to be so excessive, and people exclaimed so loudly against it, that the *Commune* of Paris determined many years since to remove the *Voirie* altogether away from the vicinity of the city. With this view they caused another place of deposit to be formed in the Forest of Bondy, about eight miles distant from Paris. This consists of eight basins, placed in two sets of four each on either side of the Canal de l'Ourcq, and each set arranged, like those of Montfaucon, one above the other in the manner of steps, so that the liquids may fall from the upper to the lower basins. The total area of these basins is 95,680 square yards (80,000 square mètres), and their collective capacity 261,385 cubic yards (200,000 cubic mètres).

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For reasons, however, which will appear presently, the intention with which this new *Voirie* was established, namely, as a substitute for that of Montfaucon, has been but partially realized. The contents of the moveable cesspools only, averaging a little over 30,000 cubic mètres annually, have been hitherto deposited in it. The moveable cesspools are first taken to a wharf on the Canal de l'Ourcq at Pantin, where they are placed on board a boat for conveyance to the basins. The empty casks are brought back by the same channel.

The quantity of matter yet sent has not been sufficient to fill the basins; there has been no necessity for draining off any excess of liquid. Should, however, the entire produce of the cesspools of Paris be ultimately sent thither, the daily addition would speedily fill the basins. It is then intended to get rid of the surplus liquids by discharging them through a pipe into the Seine, near St. Denis.

The truth, however, appears to be that the establishment of these basins in the Forest of Bondy was undertaken without any very definite notions as to the mode by which the fæcal matter was to be conveyed to them. The Canal de l'Ourcq offered a ready though costly means of transport during the greater part of the year, but in winter communication by this channel is liable to be entirely closed by frost. In 1834, about 20,000 cubic mètres were sent by canal to Bondy at a cost to the administration of 36,000 francs (1,440*l.* sterling).

Amongst other plans for obviating this acknowledged difficulty, a railway along the bank of the canal was projected, as presenting a channel of communication open with certainty at all seasons; but the idea was abandoned, I believe, chiefly on the ground of expense.

M. Mary, the able engineer to the city of Paris, proposed another plan for the conveyance of the matter to Bondy, which after having undergone a good deal of discussion, has been adopted by the administration. His plan has two features almost distinct: it provides, in the first place, depositing tanks, adjoining the Canal de l'Ourcq, at Pantin. These tanks are 27 in number, and are arranged in 3 parallel sets of 9 each. They are constructed in masonry and arched over, their upper surface being level with the ground, and they all communicate with one common exit pipe. Their collective capacity is 3,134 cubic yards (2,400 cubic mètres). Each tank is provided with an apparatus which, after the solid portion of the matter discharged into it has deposited itself, permits the fluid to be drawn or strained off;—

The set of depositing tanks communicate by means of a pipe $10\frac{5}{8}$th inches (27 centimètres) in diameter, and about 6 miles long, with the basins at Bondy. The pipe is made of rolled galvinized iron, about $\frac{1}{16}$th of an inch thick, covered externally with bitumen and lined with pitch. It is laid on an inclination upwards from the tanks to the basins.

M. Mary proposes, first, to discharge the matter extracted from the cesspools into the tanks, where it is to be allowed time for deposit; and when the solid portion shall have fallen to the bottom, the fluid is to be drawn off and forced by steam power, (a 25-horse engine having been erected for the purpose,) through the pipe into the basins at Bondy. The half-solid mass remaining is then to be raised from the tanks, by hand-pumps or other means, into casks, each containing two cubic mètres, and conveyed to the basins, as hitherto, by canal.

As far as I could learn, this plan has not been adopted on the suppo-

sition that any large portion of solid matter can be sent in suspension in the fluid through the pipe into the basins at Bondy; the anticipations on this point appear to be very moderate. Still, with matter of an average consistency, as before stated, of one of solid to four of liquid, it is pretty certain that (without dilution) the whole quantity cannot be thus disposed of. The plan, then, in its present form does not entirely obviate the objection before mentioned, as appertaining to conveyance by canal; the transit of the matter in winter being still liable to be stopped by frost. Under these arrangements, apprehension of the inconvenience which would result from such an occurrence will hardly yet permit the abolition of the *Voirie* of Montfaucon. Mr. Rammell.

IV. Concluding Observations.—Inconveniences of the Present System, and Projects for their Remedy.

Increase of Matter in the Cesspools, and proposed Mode of dealing with it.—The rapid increase of the quantity of matter in the cesspools, with the proportionately increasing expense of extracting and removing it, has long engaged the serious attention of the authorities, and many experiments have been made with a view to arriving at some plan for arresting or reducing the evil. Although none of these experiments have as yet realized any adequate practical result, it might be interesting to give a few particulars of them, in order to give a truer idea of the magnitude of a now admitted evil, and of the difficulty of framing any amendment upon a faulty principle which shall not lead to other evils almost as intolerable as that it was intended to avoid. The whole of these experiments and projects tend to show that half measures of cleanliness are almost worse than useless; and that efficient drainage and water supply must necessarily go hand in hand.

The following figures will show the increase that has taken place from 1810 to the present time:—

	Cubic Mètres.
In 1810 the total quantity of matter deposited in the basins at Montfaucon amounted to	50,151
In 1811 the quantity was	49,545
In 1812	49,235
Giving an average for the three years of .	49,877
The quantity, as before stated, at present conveyed to Montfaucon and Bondy amounts, according to M. Heloin (a very good authority), to from 600 to 700 cubic mètres daily, giving, in round numbers, an annual quantity of	230,000;

and showing an increase in 36 years of very nearly four hundred per cent.

In 1835 the Prefect of Police and the Prefect of the Seine, called together a Commission to consider this subject in connexion with the removal of the *Voirie* of Montfaucon. In a Report drawn up by certain members of the Commission, MM. Labarraque, Chevalier and Parent du Chatelet, the principal causes of this increase are stated to be:—

1. The improvements introduced in the construction of cesspools by which all leakage into the sheet of water beneath the ground, which prevailed almost universally before, is prevented.

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2. The more common use of water-closets, constructed after the English principle, which require water to keep them clear, and the greater quantity of water at command by reason of the pipes of the Canal de l'Ourcq.

3. The increased use of baths in private houses, in consequence of the more moderate price at which they are supplied.

The Report states,—

"The expense of emptying the cesspools has increased for some years past in a remarkable manner, and everything proves that it will increase more and more without its being possible to assign a limit where it will stop.

"In large mansions, where numerous servants are kept, we find already foreshadowed the future state of the cesspools generally. It is not at present as formerly, every four or five years that the cesspools of these houses are emptied, now the operation is performed two or three times in the course of a single year, and in some of them the liquids form nine-tenths of the matter extracted."

And further, referring to its effect upon the water supply:—"This city now possesses an immense mass of water which she might, in a short time, distribute throughout every quarter and in every house. The works necessary for this distribution are upon an admirable scale, but do people apply to have the water laid on to their houses in proportion as the pipes are extended? Certainly not, and one may well be surprised at the apparent indifference and apathy shown by the landlords in this respect. Some persons take advantage of this circumstance to prove that seven litres ($6\frac{1}{6}$ quarts nearly) of water are sufficient for the daily consumption of the inhabitants of Paris, while sixty litres are found necessary in London and more still in Edinburgh. But if we examine more closely this indifference of the landlords, we shall perceive that it is the result of prudence, and that it proceeds from strictly accurate calculation. The landlords, in fact, regard their cesspools with consternation; the idea of an approaching *vidange*, terrifies them. This operation, and the expense that it occasions, often influence the money value of house property. Is it likely then that in this disposition of mind they should be induced to subscribe to the water-works, when the inevitable result will be to increase the number of the operations which they most dread, and to augment their expenses in an enormous proportion? Thus, the actual state of our cesspools, and the mode of emptying them now in use, are in our view of the case the principal causes which hinder private person from laying on water to their houses, and which delay the period when the city may receive the interest for the enormous sums which it has devoted, and continues daily to devote, to obtain and complete a system of water supply."

In fine, the Commission seems to have been very fully impressed with the absolute necessity of disposing of the liquid part of the matter found in the cesspools by some less expensive method than that of transpor[t] to Montfaucon or Bondy.

After certain experiments it appears they arrive at the conclusion "that 50 parts of water are sufficient, being mixed with it, to destro[y] the taste of one part of the liquids found in the apparatus of a moveabl[e] cesspool, and that 100 parts are sufficient to cause the smell totally t[o] disappear," and they state their opinion that these liquids, mixed wit[h]

four or five times their quantity of water, might be discharged into the open gutters of the public streets with less offensive effect than the household waters, and those of a great number of manufactories which now flow upon it. Mr. Rammell.

And after weighing the respective advantages offered by the various inventions for separating the solid portion of these matters from the liquid, the Commission recommend, that when a proprietor should have caused the water of the Canal de l'Ourcq to be laid on to his house, he should have permission accorded him so to discharge into the public street the liquid contents of his cesspool, separated from the solid by a straining apparatus, the proprietor taking care to mix with them a sufficient quantity of water to neutralize their disagreeable qualities.

In considering this recommendation, it must be remembered that the principal streets of Paris only are provided with sewers, and that in many cases these liquids would have to flow over several hundred feet of shallow gutter before arriving at the nearest gully. The effect of carrying it out may then be conceived. Every house pouring fourth its stream of diluted privy liquid, to spread and evaporate over so vast a surface. Notwithstanding the opinion of the Commissioners, one may safely assert, that no practicable addition of water could smother the offensive gases, or prevent their escape into the atmosphere. The evil therefore would not be destroyed, but merely disguised.

With regard to the disposal of the solid matters, the Commissioners recommend the adoption of a process of disinfection, which should render its manufacture into *poudrette* less offensive and insalubrious, and upon the realization of this project they further recommend the complete suppression of the existing *Voirie.*

The disinfecting property of carbon has long been acknowledged :—and it appears that some years ago M. Salmon made some experiments upon a mass of mud, being the deposit from a sewer on the banks of the Seine, which containing a considerable quantity of organic matter he carbonized. "A factory was soon established to carry on further operations of the kind, and for four years past large quantities of night-soil, collected in all the villages round Paris and in Paris itself, have been dried and disinfected in this manner."

The report of the above-named Commission states :—"The discovery of M. Salmon awakened the attention of the contractors of Montfaucon, who employed one of our most skilful chemists to find for them a means of disinfection other than that for which M. Salmon had taken out a patent. M. Sanson and some other persons made similar researches, and from their joint investigations it resulted that disinfection might be equally well produced with turf ashes, with carbonized turf, and with the simple 'debris' of this very abundant substance ; and that the same success might be obtained with sawdust, with the refuse matter of the tan-yards, with garden mould, so abundant in the environs of Paris, and with many other substances. A curious experiment has even shown that after mixing with a clayey earth a portion of fæcal matter, it was only necessary to carbonize this mixture to obtain a perfect disinfectant powder. Theory had already indicated this result, for what is fæcal matter but a compound of vegetable and animal matters?"

In short it was found that the disinfection of the fæcal matter of cesspools had already been carried on to a considerable extent by the above-

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cited process, and the commission of 1835 recommended the still further application of the principle. The Report states:—

"The first thing to be done, should be to obtain a modification of the manner in which the manufactories of *poudrette* are classified. In the first class should be placed those manufactories working by the methods in common use, and in the second class those which employ less offensive means.

"This modification obtained, the administration might declare that the working and the preparation of the matters, the produce of the cesspools by means not insalubrious, re-entered in the domain of public industry, and that any one would be free to take to it, upon conforming to the regulations which it might be thought proper to impose, according to the particular conditions of each locality.

"The inevitable result of this declaration would be the creation in the environs of Paris of 10, 15, or 20 spots destined to these sort of preparations, an inestimable advantage, not only as regards the economy of transport, but even in a greater degree as respects the public health; for even supposing that which appears to us impossible, that some bad smells emanated from these establishments, they would always be in such small volume that they would hardly pass beyond the gates.

In another report by M. Parent du Chatelet, he thus describes the particular process of disinfection:—

"Before the Commissioners, MM. Salmon, Payen, and Company, caused two pails full of the liquid matters of the cesspools to be poured into a vessel; they threw upon these matters an absorbent carbonized powder, and in the space of two minutes, watch in hand, the disinfection was so complete that the Commissioners could take handfulls of this new substance, place it to the nose, and only distinguish a slight ammoniacal smell, fresh, and without the least trace of animal matter. So prompt and complete was the operation, even the hands of the workman who had mixed and stirred the composition were free from smell.

"The Commissioners caused the experiments to be repeated upon a whole tub full of fæcal matter, and in the space of five minutes the results were as satisfactory as in the experiment on the small scale."

"So powerful is the disinfectant property of this substance, that it will destroy the stench arising from putrid entrails as easily as that given off by fæcal matters. The Commissioners have witnessed this on several occasions with much surprise."

M. Paulet states:—

"The excretions are, by these means, so perfectly disinfected, that M. Darcet placed some of the powder resulting from the process in a China saucer, and caused it to be handed about one evening in his salon in the midst of a numerous society, giving it out for a certain mineral. Great was the surprise of his guests when he informed them afterwards what was the real nature of the pretended mineral."

The Commissioners are completely silent upon so important a point as the cost of carrying out the new system they propose, which there can be no doubt from the large proportion of the carbonised material requisite to produce complete disinfection, would, in transport alone, be very considerable.

Notwithstanding all their investigations, experiments, and strong recommendations, the new project has been carried out to a very limited

extent. The last of these reports was written so far back as 1835, and the great bulk of the solid produce of the cesspools of Paris contained within the barriers is still conveyed to Montfaucon as described in a former part of this paper, where it is manufactured into *poudrette* in the manner practised at that time, and which had been practised for ages before.

Expense of the Cesspool System compared with that of Tubular Drainage.—I shall now endeavour to calculate the cost of the cesspool system, as carried out in Paris, and the annual expense of it, per head of population. I shall then compare the expense of this system with the estimated expense of a system of tubular drainage; and afterwards very cursorily consider the advantages, in an economical point of view, of substituting, in Paris, the latter system of drainage for the cesspool system at present in operation.

The first point to determine, in making these calculations, is the actual cost of the working of the present cesspool system in Paris.

The daily quantity of matter at present withdrawn from the cesspools is, as before stated, between 600 and 700 cubic mètres; giving, in round numbers, the annual quantity of 230,000 cubic mètres. The average charge per cubic mètre for extraction and transport is 9 francs, giving a gross annual charge of 2,070,000 francs (82,800*l.* sterling), which sum, it would appear, is paid every year by the house-proprietors of Paris for the extraction of the matter from their cesspools, and its transport to the *Voirie.*

Dividing this annual quantity of 230,000 cubic mètres by the number of the population of Paris (945,721 individuals according to the last census), we have 243 litres only as the annual produce from each individual. The daily quantity of matter (including water) passing from each person into the cesspool has been before stated to be $1\frac{3}{4}$ litres (3·08 pints), or 638 litres annually. The discrepancy between these two quantities, wide as it is, must be accounted for by the fact of a large proportion of the lower orders in Paris rarely or ever using any privy at all, and by allowing for the small quantity of water made use of in the privies of the inferior class of houses. There can be no doubt that this latter quantity of $1\frac{3}{4}$ litres daily is very nearly correct, and not above the average in houses where a moderate degree of cleanliness is observed. This proportion was ascertained to hold in the case of some barracks in Paris, where the contents of the cesspools were accurately measured, the total quantity divided by the number of men occupying the barracks, and the quotient by the number of days since the cesspools had been last emptied; the result showing a daily quantity of $1\frac{3}{4}$ litres from each individual. The correctness of this estimate too has been confirmed, as M. Heloin assured me, by the experience of the Compagnie Richer in the case of private houses.

The average cost of construction of each cesspool, it has been already stated, cannot be estimated at less than 18*l.* sterling. It is common, however, in Paris for a single house to have two or three cesspools, placed to suit local convenience, in different parts of the premises. Supposing the average to each house not to exceed one and a-half, and the cost of each cesspool to be 18*l.* sterling, we shall have a capital of 27*l.* sterling per house sunk in works of construction of

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cesspools. The average number of inmates per house in Paris is 24 persons.

Adopting these calculations of the number of cesspools to each house and their cost, and allowing only the small quantity of $1\frac{3}{4}$ litres (3·08 pints) of matter to each individual, the annual expense of the cesspool system in Paris per house containing 24 persons will be: for interest, at five per cent. upon capital sunk in works of construction, 1*l.* 7*s.*; for extraction and removal of matter, 5*l.* 11*s.*; total, 6*l.* 18*s.*; the annual expense per inhabitant will be 5*s.* 9*d.*

This latter, then, may be taken as the average yearly sum per head actually paid by that portion of the inhabitants of Paris who use the cesspools. We will now turn to consider the estimated cost of the system of tubular drainage applied to a middle class house in London.

Upon the basis of the estimates given in the First Report of the Metropolitan Sanitary Commissioners, the cost for works of construction of a tubular system of refuse drainage may be set down at the rate of 4*l.* 3*s.* per house of eight inhabitants. This estimate includes not only the house-drains, but also a fair share of the public sewers necessary for the conveyance of the refuse matter away from the habitation, to a distant outfall, and is intended to represent the whole cost of the system, to an ordinary middle class house, containing eight inhabitants. The total annual cost of the system then will be comprised in the interest upon capital sunk in works, which, at 5 per cent., will amount to 4*s.* 2*d.* per house, or $6\frac{1}{4}$*d.* per inhabitant, being less than one-tenth part of the charge per inhabitant entailed by the cesspool system according to the preceding calculation. It should be observed, however, that in the case of houses situated in low districts, where, in order to effect the discharge of the refuse at a sufficient distance from the site of the city, it would be necessary to pump it up by engine-power, an additional charge, amply covered by a rough estimate of 2*s.* per house, must be reckoned upon. But even allowing the extra charge for pumping, a very considerable pecuniary balance, amounting to several hundreds per cent. would be found to be due to the tubular over the cesspool system.

In order to test the accuracy of these estimates I will now refer to evidence recently given before the Board of Health, by three of the officers of the Metropolitan Commissioners of Sewers, who may be supposed to have had the greatest practical experience on the subject.

Mr. Lovick, the Surveyor for the Westminster District, gives the case of a block of nearly 1,200 houses, of "a medium middle class," in and near Earl-street, and he estimates the entire cost, public and private, of a system of tubular drainage, including water-closet pan, &c., at about 4*l.* 8*s.* per house.

Mr. Grant, the Surveyor for the Surrey and Kent District, states, in the case of a block of 44 houses, of about 15*l.* rental, the estimated cost of tubular drainage, exclusive of pans, traps, &c., at 1*l.* 18*s.* per house; in another case of a block of 23 houses, at 1*l.* 19*s.* 8*d.* per house; in another block of 46 houses, at 1*l.* 8*s.* $9\frac{3}{4}$*d.* per house; and in a fourth block of 46 houses, at 1*l.* 8*s.* $10\frac{1}{2}$*d.* per house.

Mr. Gotto, Surveyor for the Holborn District, in the case of a block of houses of the inferior class, covering an area of about 9 acres, and situate in Goulstone-street, Whitechapel, estimates the whole cost of

private drainage, including the fitting up of existing cesspools, water-closet with stool cock, and kitchen and yard sinks complete, at 3*l.* 2*s.* 9½*d.* per house; and the proportion of the expense of main sewers at 1*l.* 9*s.* 6*d.* per house; making a total of 4*l.* 11*s.* 9*d.* per house. Exclusive of the cost of filling up the cesspools, however, the cost per house would be for private drainage, 1*l.* 9*s.* 7½*d.* per house, which, added to the proportion of expense of public sewers, (1*l.* 9*s.*) would give 2*l.* 18*s.* 7½*d.* per house, as the whole expense of a system of tubular drainage. Mr. Rammell.

These cases, coming from the quarters they do, will I think be sufficiently corroborative of the liberality of the estimate upon which I have argued in a preceding paragraph, of 4*l.* 3*s.* 6*d.* per house of an ordinary class, for the laying down of a system of tubular drainage.

Even this, however, does not represent the full difference in the expense of the two systems. The cesspool does not receive the water that has been used for cleansing and culinary purposes, nor the surface water of the streets and houses, and sewers and drains have still to be provided to convey away this portion of the liquid refuse. While with the tubular system of refuse drainage, the same channels that carry away the fæcal matter from the houses are open to receive the fluids derived from the other sources that have been mentioned, and one outlay, one system of pipes, one staff of superintendents, will serve for the accomplishment of both objects.

Let us now see whether the tubular system of drainage, the abstract superiority of which I will suppose to be admitted, might not even at this time be applied to Paris, not only without inflicting any increased charge upon the inhabitants, but even with a positive saving to them of a considerable portion of their current outlay for the extraction and removal of the contents of their cesspools. For this is the only point of view in which the comparison may be instituted with any chance of a practical result, in the case of a town already fully provided with a system of cesspools, however vicious and inconvenient that system may have been shown to be. The outlay upon works of construction having already been undertaken and liquidated, it would not be a sufficient inducement to the people of Paris to adopt a new system, to tell them that their money has been badly expended, and that, for a less sum, they might now construct a tubular system of drainage, which would render their cesspools unnecessary for the future. In advocating a change of system to practical men, we must start from the point at which we stand, and it is of importance to show that the absolute current expenses attaching to the existing system, might be made sufficient for the substitution of all works of construction necessary for the improved system, as well as all annual charges for the working of it; and if in addition it can be shown that a balance will then absolutely remain in hand at the end of each year to be carried to the credit of the new system, we offer an amount of inducement, both in increased cleanliness and comfort, and in pecuniary gain, which few rational men would refuse to listen to.

I propose now to show (adopting a very rough estimate), that it would be perfectly feasible to establish a system of tubular drainage in Paris, by the economical use of an annual income, much under the

Mr. Rammell. amount at present expended by the inhabitants in the extraction and removal of the contents of their cesspools.

The annual amount so expended in Paris is, in round numbers, over 82,000*l.*

In forming an estimate of the probable cost of laying down a tubular system of drainage in Paris, as founded upon the foregoing estimates, it might be proper to bear in mind a fact already incidentally referred to, viz., that as the houses in Paris are much loftier than those in London, and the average number of inhabitants to each much greater, the average extent of mileage of any sewers or drains to be laid down for their use would be proportionably less per head. Accordingly, we find that the area of Paris is only about one-fourth that of London; or, in proportion to population, one-half. The force of this position would appear to be so obvious that it seems necessary to do no more than make a very casual reference to it, the more particularly, as in the general calculations I am about to make, I do not intend to take advantage of it for the purpose of reducing the estimate of cost of the application of the proposed system.

I shall assume then, the cost for works of construction in Paris, where the houses average 24 inhabitants each, to be after the same rate per head as in London, where the houses do not average 8 inhabitants each; namely, about 10*s.* 6*d.* per head, or 12*l.* 12*s.* per house. This, for a population of a million, in round numbers, would give a gross outlay for works of construction of a system of tubular drainage of 525,000*l.*; or, including a long length of outfall pipe, say of 600,000*l.*; the annual interest of which, at 5 per cent. would be 30,000*l.* Supposing that in the case of one-third of Paris, engine power would be required for the purpose of pumping the refuse, an additional sum of 5,000*l.** (which experience would show to be more than ample) may be allowed for it. Adding to this 5,000*l.* for charges of management, the whole annual expense of removing, by means of a system of tubular drainage, the refuse of Paris beyond the boundaries of the city to a spot where its accumulation would not create a nuisance, would be 40,000*l.*, which, being deducted from 82,800*l.*, the actual cost of the working of the present cesspool system (apart from the cost of works of construction) would leave a clear balance or saving of more than 42,000*l.* a-year.

The above calculation is founded upon the present cost of the working of the cesspool system in Paris. It should be borne in mind, however, that of late years this cost has been constantly on the increase (to the extent of nearly 400 per cent. in the last 36 years), and that there is every probability of its still increasing, without any assignable limit. In this view of the case, the saving to be affected by a timely application of the tubular system becomes proportionably more important. As an additional circumstance tending to favour the adoption of a tubular system of refuse drainage in Paris, it should be borne in

* I suggest this item of expenditure merely to be on the safe side; though, from a general observation of the site of Paris, I think it more than probable that the drainage of even the lowest parts of the city might be discharged at a point down the valley of the Seine, sufficiently remote for sanitary purposes, by natural means only. Paris has this advantage over London, that it is placed above the influence of the tide.

mind that most of the houses are already provided with pans upon nearly every floor, and with the pipes necessary for conducting the matter below the basement; the only private works remaining to be effected, supposing the public works to have been completed, would be to divert the point of discharge of these tubes from the existing cesspools to the main arteries of the system of drainage so laid down in the streets. The refuse would thus on the instant of production be put in course of conveyance to a distance from the town, at the rate of probably about 3 miles per hour, instead of stagnating and fermenting as at present for months together, until removed by a complicated, laborious, costly and offensive process. Mr. Rammell.

Conclusions.—From the facts detailed in the above description of the cesspool system of Paris, we may conclude,—

1. That this system, to be well carried out, requires, both in its works of construction and in those of extraction and transport of the fæcal matter; most comprehensive and detailed regulations, involving wide-extended supervision, and constant, minute, and difficult inspection, to ensure their observance.
2. That with the most perfect regulations and supervision, and the application to the purpose of machines constructed upon scientific principles, the operation of emptying a cesspool is still a nuisance, not only to the inmates of the house to which it belongs, but to those of the neighbouring houses, and to persons passing in the street; and that a place of deposit being necessary for the matter extracted, the system unavoidably entails a wide-spreading and most disgusting public nuisance upon some point or other of the environs of the city where it is adopted.
3. That the cesspool system presents an obstacle to the proper extension of the water supply, and consequently represses the growth of habits of personal and domestic cleanliness, with their immense moral results; and that in this respect it may be said to be inconsistent with a high degree of civilization of the masses of any community.
4. That, compared with a tubular system of refuse drainage, it is an exceedingly expensive mode of disposing of the fæcal refuse of a town, so much so, that even in Paris the existing cesspools might be abandoned, and a system of tubular drainage substituted, for a considerably less annual sum, including interest for capital sunk in works of construction, than is now spent in emptying the cesspools; whilst viewed in connexion with the whole subject of town drainage, it is seen to involve an expense at once serious and altogether useless and unnecessary.

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APPENDIX.

NOTE ON THE USE OF "POUDRETTE."

In connection with this subject, a few observations upon the application of *poudrette* in agricultural processes may not be without interest.

With regard to the fertilizing properties of this preparation, M. Maxime Paulet, in his work entitled "Theorie et Pratique des Engrais," gives a table of the fertilizing qualities of various descriptions of manure, the value of each being determined by the quantity of nitrogen it contains. Taking for a standard good farm-yard dung, which contains on an average 4 per 1,000 of nitrogen, and assuming that 10,000 kilogrammes (22,046 lbs. English) of this manure (containing 40 kilogrammes of nitrogen) are necessary to manure one hectare ($2\frac{1}{2}$ acres nearly) of land, the quantities of *poudrette* and of some other animal manures required to produce a similar effect would be as follows:—

	Kilogrammes.
Good farm-yard dung, the quantity usually spread upon one hectare of land	10,000
Equivalent quantities of human urine, not having undergone fermentation	5,600
" " *poudrette* of Montfaucon . .	2,550
" " mixed human excrements (this quantity I have calculated from data given in the same work) . .	1,333
" " liquid blood of the abattoirs . .	1,333
" " bones	650
" " average of guano (two specimens are given)	512
" " urine of the public urinals in fermentation and incompletely dried .	233

Mr. Paulet estimates the loss of the ammoniacal products contained in the fæcal matters when they are withdrawn from the cesspools, by the time they have been ultimately reduced into poudrette at from 80 to 90 per cent.

I have not been able to meet with an analysis of the matters found in the fixed and moveable cesspools of Paris, but in the "Cours d'Agriculture," of M. le Comte de Gasparin, I find an analysis by MM. Payen and Boussingault of some matter taken from the cesspools of Lille, and in the state in which it is ordinarily used in the suburbs of that city as manure. This matter was found to contain on the average 0·205 per cent. of nitrogen, and thus by the rule observed in drawing up the above table, 19·512 kilogrammes of it would be necessary to produce the same effect upon one hectare of land as the other manures there mentioned. The wide difference between this quantity and that (1,333 kilogrammes) stated for the mixed human excrements in their undiluted state, would lead to the conclusion that a very large proportion of water was present in the matter sent from Lille, unless we are to attribute a portion of the difference to the accidental circumstance of the bad quality of this matter. It appears that this is very variable, according to the style of living of the persons producing it. "Upon this subject," M. Paulet says, "the case of an agriculturist in the neighbourhood of Paris is cited, who bought the contents of the cesspools of one of the fashionable *restaurants* of the 'Palais Royal.' Making a profitable speculation of it, he purchased the matter of the cesspools of several barracks. This bargain, however, resulted in a loss, for the produce from this last matter came very short of that given by the first."

Poudrette weighs 70 kilogrammes the hectolitre (154 lbs. per 22 gallons), and the quantity usually spread upon one hectare of land ($2\frac{1}{2}$ acres nearly) is 1,750 kilogrammes, being at the rate of about 1,540 lbs. per acre English measure. It is cast upon the land by the hand, in the manner that corn is sown.

M. de Gasparin says, "Poudrette gives great activity to vegetation, but its effects are soon exhausted, and it is thought that sometimes they are not prolonged even to the period of fructification of farinaceous plants. It promotes great vigour in herbage, but it is said to communicate a flavour to it which is distasteful to cattle. It is for this

reason also that gardeners refuse to employ manures of this class, which emit in a short space of time large quantities of ammoniacal vapours to be absorbed and retained by the leaves." *Poudrette* is not applied to the market gardens or in agriculture in the immediate vicinity of Paris, nor within a circle of four or five leagues around it. Besides the reason stated by M. de Gasparin as inducing gardeners to reject it, it is of too heating a nature to suit the light, dry, calcareous soil of this district—and even if its qualities accorded well with the soil, it could not be supplied at a price to enable it to compete with the stable manure furnished in such enormous quantities by the city, in addition to its other refuse which is valuable as manure. I am informed that the cold clay soils derive much advantage from poudrette.

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Poudrette packed in sacks very soon destroys them. This is always the case, whether it is old or has been newly prepared.

A serious accident occurred in 1818, on board a vessel named the "Arthur," which sailed from Rouen with a cargo of *poudrette* for Guadaloupe. During the voyage a disease broke out on board which carried off half the crew, and left the remainder in a deplorable state of health when they reached their destination. It attacked also the men who landed the cargo; they all suffered in a greater or less degree. The poudrette was proved to have been shipped during a wet season, and to have been exposed before and during shipment in a manner to allow it to absorb a considerable quantity of moisture. The accident appears to have been due to the subsequent fermentation of the mass in the hold—increased to an intense degree by the moisture it had acquired, and by the heat of a tropical climate.

M. Parent du Chatelet, to whom the matter was referred, recommended that, to guard against similar accidents in future, the poudrette intended for exportation, in order to deprive it entirely of humidity, should be mixed with an absorbent powder, such as quick lime, and that it should be packed in casks to protect it from moisture during the voyage.

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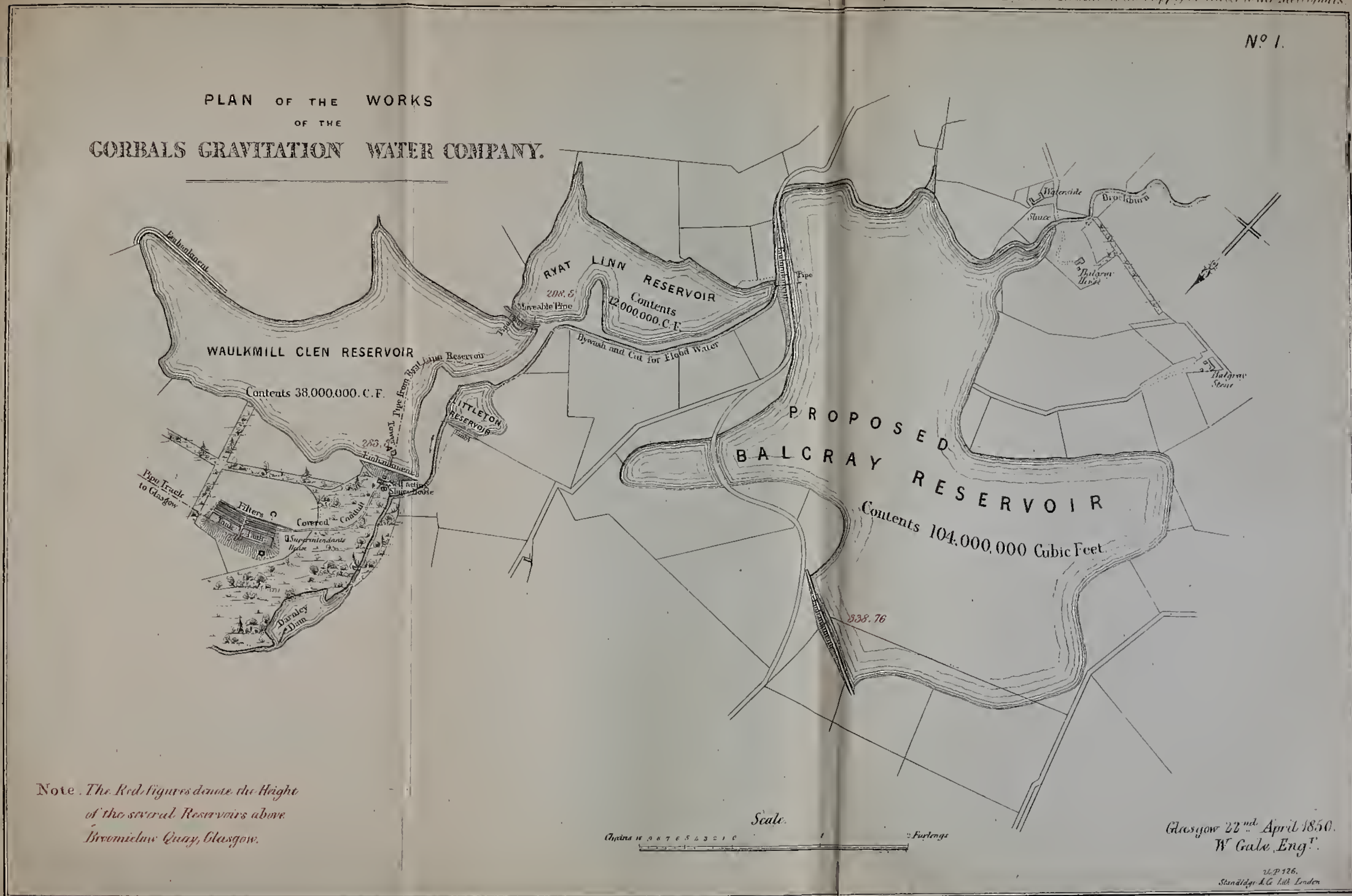
For Her Majesty's Stationery Office.


No 1.
PLAN OF THE WORKS
OF THE
CORBALS GRAVITATION WATER COMPANY.
WAULKMILL GLEN RESERVOIR
Contents 38,000,000. C. F.
Embankment
RYAT LINN RESERVOIR
Contents
12,000,000. C. F.
208. 5
Moveable Pipe
Byewash and Cut for Flood Water
Pipe from Ryat Linn Reservoir
LITTLETON RESERVOIR
283. 6
Self acting Sluice House
Filters
Covered Conduit
Superintendants House
Pipe Track to Glasgow
Darnley Dam
PROPOSED
BALCRAY RESERVOIR
Contents 104,000,000 Cubic Feet.
338. 76
Pipe
Waterside
Sluice
Brockburn
Balgray House
Balgray Stone
Note. The Red figures denote the Height of the several Reservoirs above Broomielaw Quay, Glasgow.
Scale.
Chains
Furlongs
Glasgow 22nd. April 1850.
Wr Gale, Engr.
Standidge & Co. Lith. London

No 2.

SECTION,
SHOWING PART OF THE WORKS
OF THE
GORBALS GRAVITATION WATER COMPY
THROUGH LINE A.B.C.D. ON PLAN.

Glasgow 22nd April 1850.
W. Gale, Engr.

25. p. 126.
Standidge & Co. Litho 36 Old Jewry

No. 3.

PLAN OF FILTERS &c. OF THE GORBALS GRAVITATION WATER COMPANY.

Glasgow, 22nd April, 1850.
W. Gale, Engineer

Standidge & Co. Litho. Old Jewry

No 4.

SECTION OF THE RESERVOIRS AND PIPE TRACK OF THE GORBALS GRAVITATION WATER COMPANY.

Glasgow, 22nd April, 1850.
W. Gale. Engr

27 T462
Standidge & Co Litho London.

N°5.

SECTION
SHOWING PART OF THE WORKS
OF THE
KILMARNOCK WATER COMPANY.

Glasgow 22^d April, 1850.
W. Gale. Eng^r.

24 P. 162
Standidge & Co. Litho. Old Jewry

No 6.

STRANRAER WATER WORKS.

DRAWING OF MOVEABLE PIPE.

Glasgow, 22nd April, 1850.
W. Gale. Engr.

29. P. 162.

Standidge & Co. Litho. 36, Old Jewry.

ANALYSIS OF 17 SAMPLES OF WATER.

Saline and other matter in One Imperial Gallon of 70,000 Grains.	GRAHAM 1844			BRANDE 1846			PHILLIPS 1849			BOSTOCK 1834	BEALE 1841		BRANDE 1846				COLLEGE
	Greenwich Hospital	Page's Well, Greenwich.	Lambert's Well, Deptford.	Brewery, London.	Charing Cross.	Royal Mint.	Camden Town Station.	Watford Station.	Tring Station.	Treasury Pump.	Robarts, Roehampton.	Robarts, Roehampton.	Thames, Chelsea.	River Colne.	New River.	River Lea.	TRAFALGAR SQUARE.
	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.
Carbonate of Lime.	19.08	21.23	16.74	6.2	3.1	1.5	. .	19.54	14.72	34.3	48.0	24.0	16.5	18.1	14.7	10.2	3.27
Carbonate of Soda.	. .	. .	. .	11.7	14.6	12.0	17.60	. .	. .	. .	. .	. .	. .	. .	. .	. .	18.28
Sulphate of Soda.	3.62	0.60	2.67	24.2	19.6	18.1	13.0	. .	. .	. .	8.0	8.0	. .	. .	. .	. .	8.74
Sulphate of Lime. C. Iron	0.52	. .	. .	. .	. .	. .	. .	0.94	1.09	16.1	32.0	24.0	1.5	1.2	1.6	6.2	. .
Muriate of Soda.	0.37	3.12	1.91	12.7	25.7	8.3	11.10	1.90	1.38	12.6	16.0	8.0	1.7	2.0	1.7	6.6	20.05
Carbonate of Magnesia.	. .	. .	0.84	1.1	2.4	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	2.25
Sulphate of Magnesia.	2.04	2.88	2.75	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	.	Sulphate of Potash		13.67
Carbonaceous Matter.	. .	. .	. .	. .	. .	. .	2.30	1.32	1.61	. .	. .	. .	t	t	1.2	2.4	0.68
Silica.	. .	. .	. .	0.4	0.7	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	0.97
Phosphates.	. .	. .	. .	0.4	t	t	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	2.03
Loss.	1.67	. .	1.33	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Total	27.30	27.83	26.24	56.7	66.1	39.9	44.0	23.7	18.8	63.0	104.0	64.0	19.7	21.3	19.2	25.4	69.94

TABLE

SHEWING THE DECLINE OF, AND THE EFFECT OF PUMPING ON THE WATER IN THE SAND SPRING UNDERLYING THE BLUE AND PLASTIC CLAYS IN LONDON, TAKEN FROM MESSRS COMBE'S BREWERY, CASTLE STREET, LONG ACRE, BEING 173 FT DEEP.

Water Level in 1827 - 75 Feet from Surface.

	1837	1838	1839	1840	1841	1842	1843	1844	1845	1846	1847	1848	1849
	Ft In	Ft In	Ft In	Ft In	Ft In	Ft In	Ft In	Ft In	Ft In	Ft In	Ft In	Ft In	Ft In
January	.	113 . 6	118 . 0	119 . 0	119 . 0	126 . 0	130 . 0	131 . 0	137 . 0	140 . 0	133 . 8	139 . 0	148 . 6
February	.	114 . 0	118 . 0	119 . 0	121 . 0	125 . 9	130 . 9	133 . 0	136 . 0	140 . 9	134 . 8	144 . 0	150 . 9
March	.	116 . 0	116 . 9	116 . 0	121 . 6	126 . 6	130 . 0	135 . 6	132 . 6	140 . 0	133 . 11	145 . 3	152 . 6
April	.	113 . 6	116 . 6	118 . 0	122 . 0	124 . 0	129 . 0	133 . 0	135 . 9	139 . 0	135 . 2	142 . 0	150 . 9
May	.	114 . 6	115 . 9	121 . 0	123 . 0	128 . 0	129 . 0	133 . 0	138 . 0	146 . 6	135 . 11	141 . 0	153 . 0
June	.	113 . 0	116 . 0	119 . 6	124 . 0	130 . 6	129 . 0	137 . 0	139 . 0	142 . 9	139 . 10	147 . 0	158 . 0
July	116	113 . 3	117 . 6	120 . 0	125 . 6	131 . 0	130 . 9	138 . 3	139 . 6	146 . 3	146 . 6	153 . 0	160 . 9
August	116 . 0	113 . 0	119 . 0	120 . 0	124 . 6	128 . 0	133 . 0	135 . 6	138 . 0	144 . 3	147 . 0	150 . 9	163.6
September	116 . 0	118 . 0	117 . 0	121 . 6	124 . 3	131 . 0	134 . 0	134 . 6	139 . 0	140 . 3	146 . 0	151 . 0	160 . 6
October	115 . 0	118 . 0	117 . 0	121 . 0	124 . 0	130 . 6	132 . 6	„ „	139 . 6	139 . 6	143 . 6	147 . 6	158 . 0
November	114 . 0	117 . 6	117 . 0	120 . 0	121 . 0	131 . 0	130 . 6	135 . 0	138 . 3	135 . 3	142 . 6	145 . 3	159 . 0
December	113	117 . 0	115 . 0	119 . 0	124 . 6	130 . 0	132 . 0	135 . 6	137 . 0	133 . 0	140 . 0	147 . 6	155 . 9

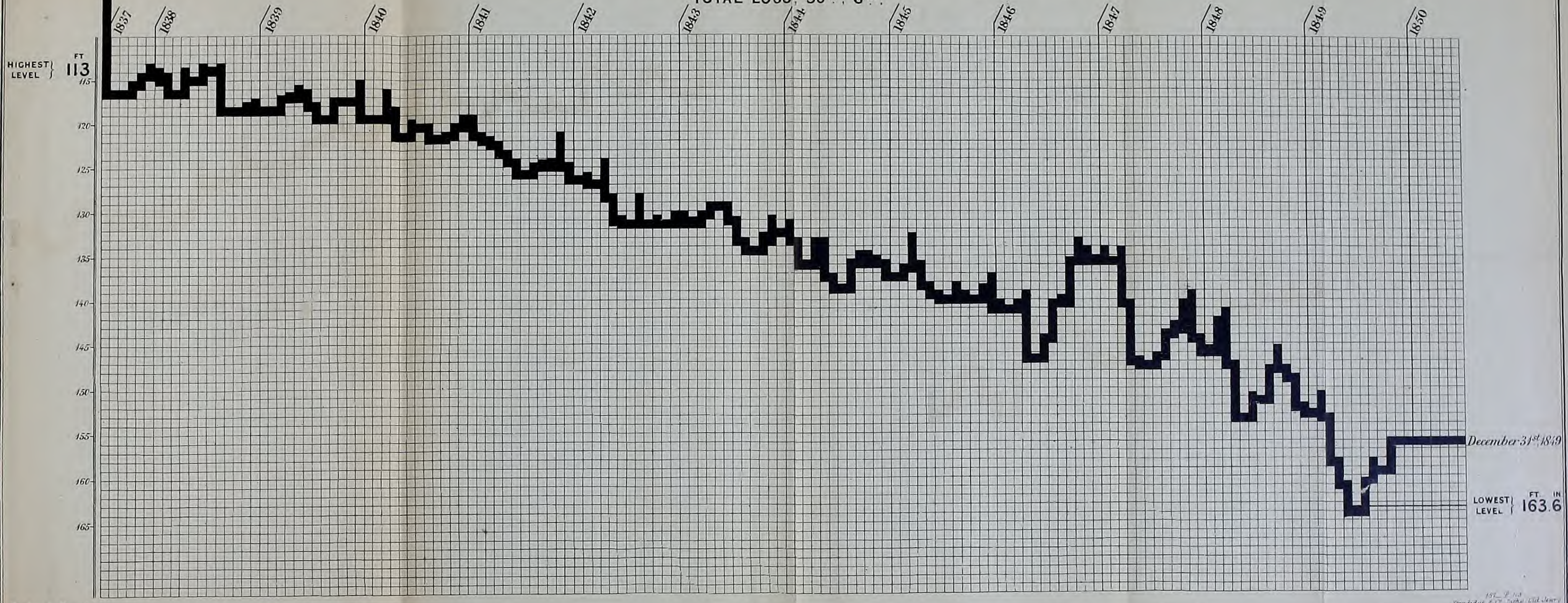
Frederick Braithwaite, Jan. 29th 1850

Standidge & Co. Litho. Old Jewry

DIAGRAM,

SHEWING THE FALL OF WATER IN THE SAND SPRING UNDERLYING THE BLUE AND PLASTIC CLAYS UNDER LONDON, TAKEN AT MESSRS COMBE AND DELAFIELD'S BREWERY, CASTLE STREET, LONG ACRE. FROM AUGUST 1837, TO DECEMBER 1849 INCLUSIVE.

TOTAL LOSS, 50 FT. 6 IN.

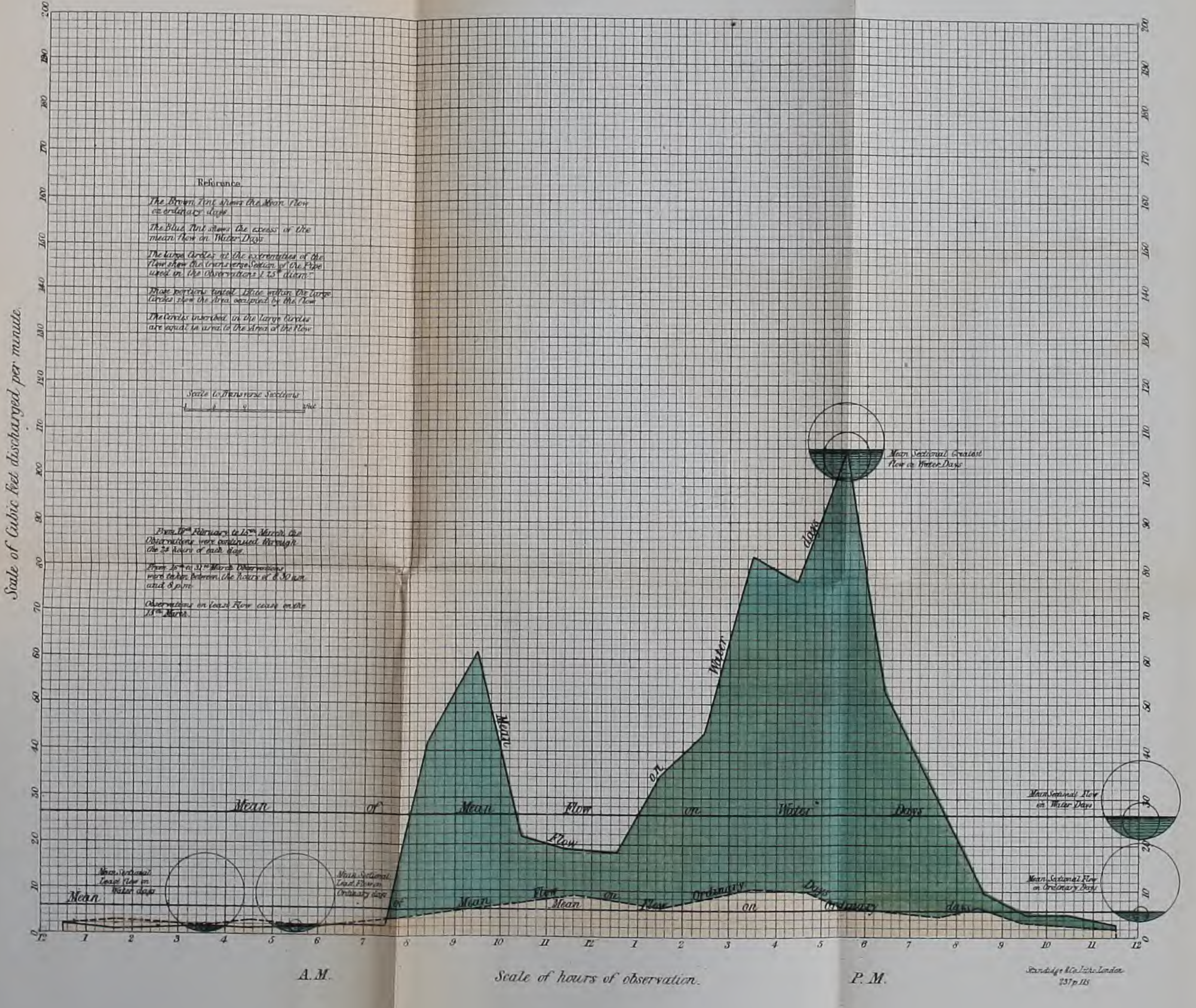


Frederick Braithwaite

Standidge & Co. Litho. Old Jewry

HYDRAULIC EXPERIMENTS. TABLE B.

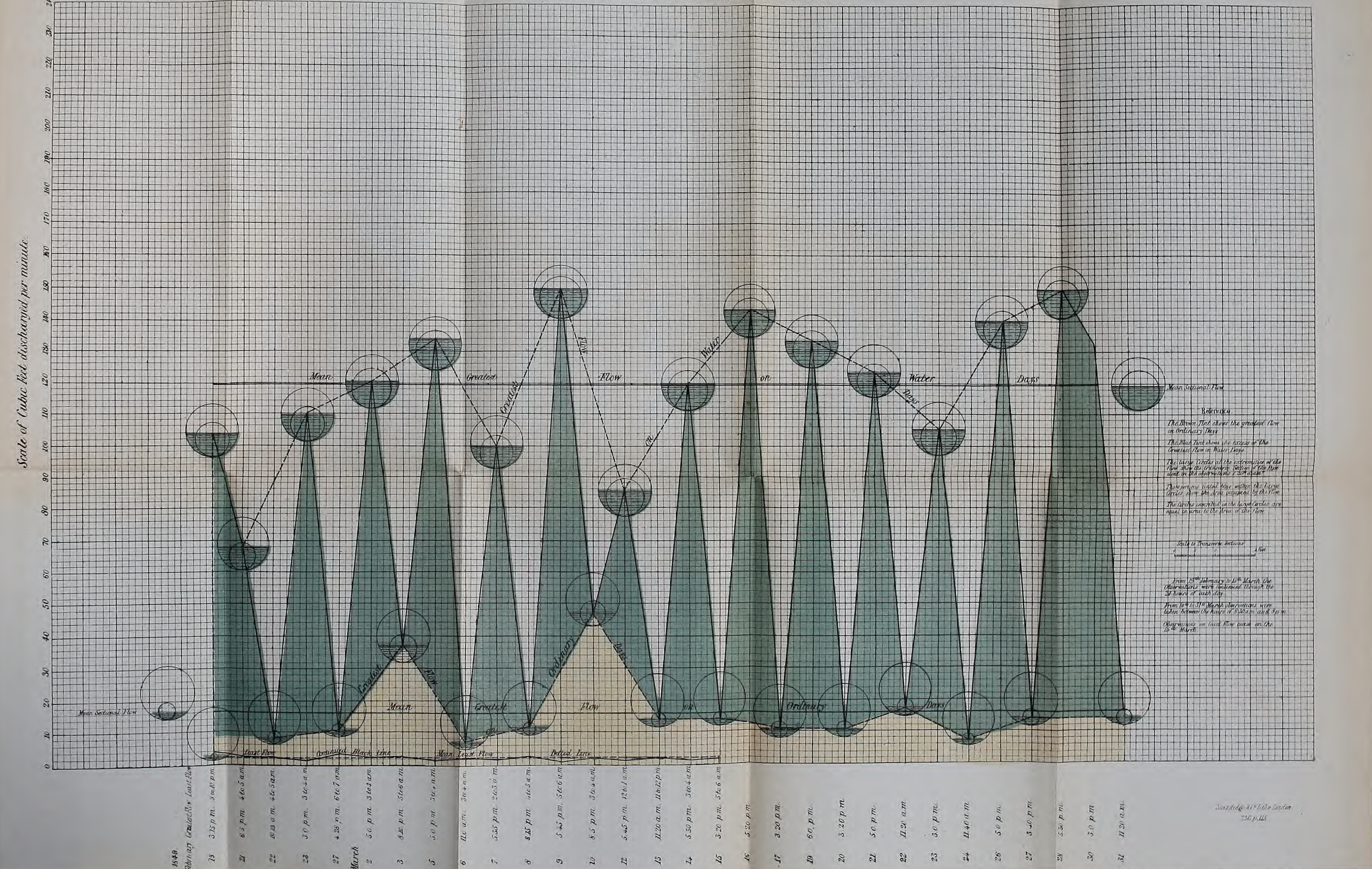
On Flow of Sewage through Glazed stone-ware pipes laid in the Earl Street Sewer.
Diameter of pipes 1.25 feet._ Length of pipes 116 feet._ Inclination of pipes 1 in 153.
Area draining into Sewer 43.656 Acres._ Houses on Area drained 1315._ Houses draining into Sewer 1135.
Mean Flow due to House drainage only.
On Water Days mean of 16 Days observations} ---From 19th February to 31st March 1849.
On Ordinary . . 14 . .

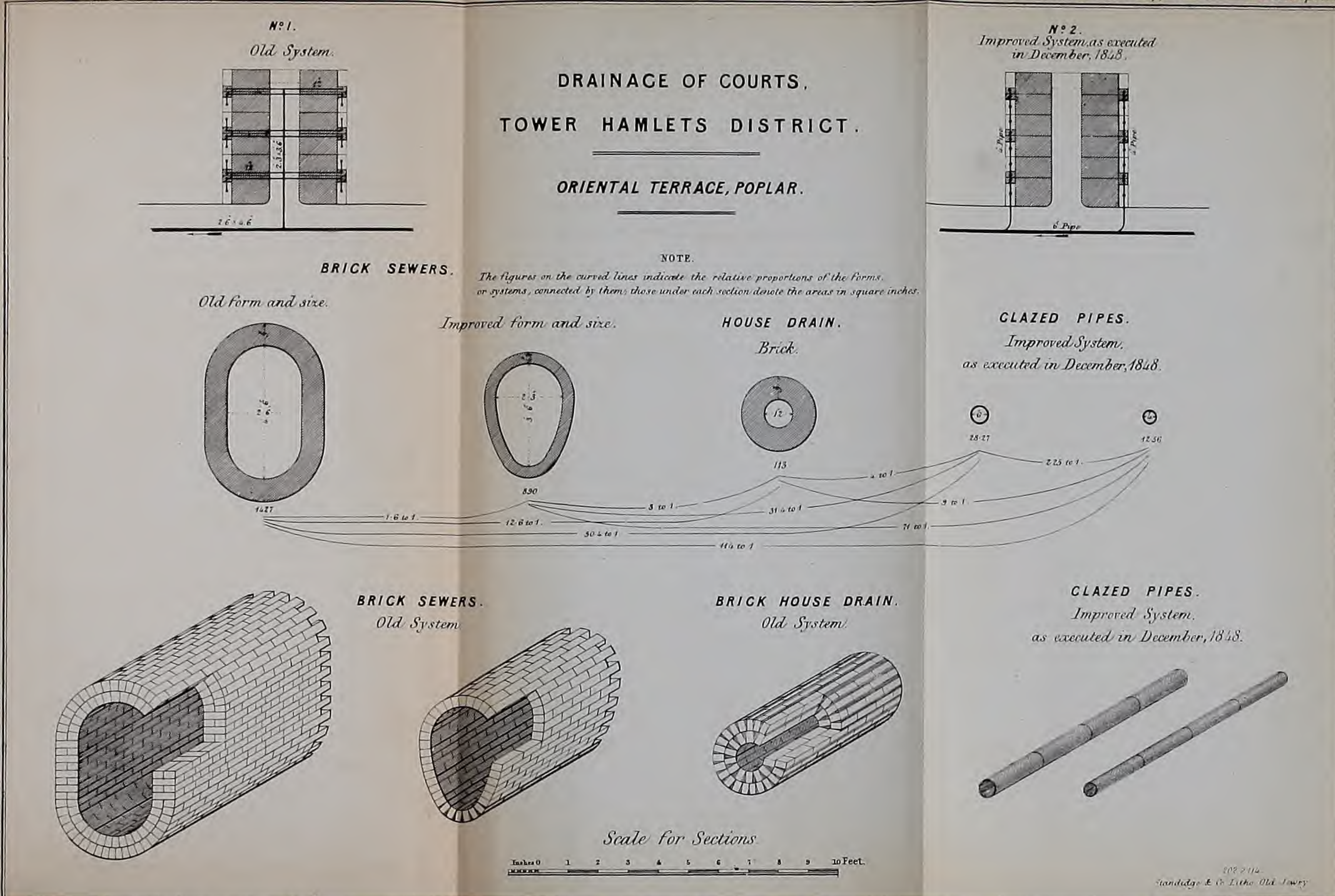


Standidge & Co. Litho. London.

HYDRAULIC EXPERIMENTS, TABLE A.

On flow of Sewage through Glazed stone ware pipes laid in the Earl Street Sewer.
Diameter of pipes 1·25 feet. Length of pipes 115 feet. Inclination of pipes 1 in 153.
Area draining into Sewer 43,656 Acres. Houses on Area drained 1515. Houses draining into Sewer 1155.
Shewing the greatest flow due to House drainage only
From 19th February to 31st March 1849.




DRAINAGE OF COURTS.
TOWER HAMLETS DISTRICT.
ORIENTAL TERRACE, POPLAR.
Nº 1.
Old System.
2.6 × 4.6
2.3 × 3.6
Nº 2.
Improved System, as executed in December, 1848.
4 Pipe
6 Pipe
BRICK SEWERS.
NOTE.
The figures on the curved lines indicate the relative proportions of the forms, or systems, connected by them; those under each section denote the areas in square inches.
Old form and size.
Improved form and size.
HOUSE DRAIN.
Brick.
GLAZED PIPES.
Improved System, as executed in December, 1848.
1427
890
113
28.27
12.56
1.6 to 1.
12.6 to 1.
50.4 to 1.
114 to 1.
8 to 1.
31.4 to 1.
71 to 1.
4 to 1.
9 to 1.
2.25 to 1.
BRICK SEWERS.
Old System.
BRICK HOUSE DRAIN.
Old System.
GLAZED PIPES.
Improved System, as executed in December, 1848.
Scale for Sections.
Inches 0 1 2 3 4 5 6 7 8 9 10 Feet.
Standidge & Co Litho Old Jewry

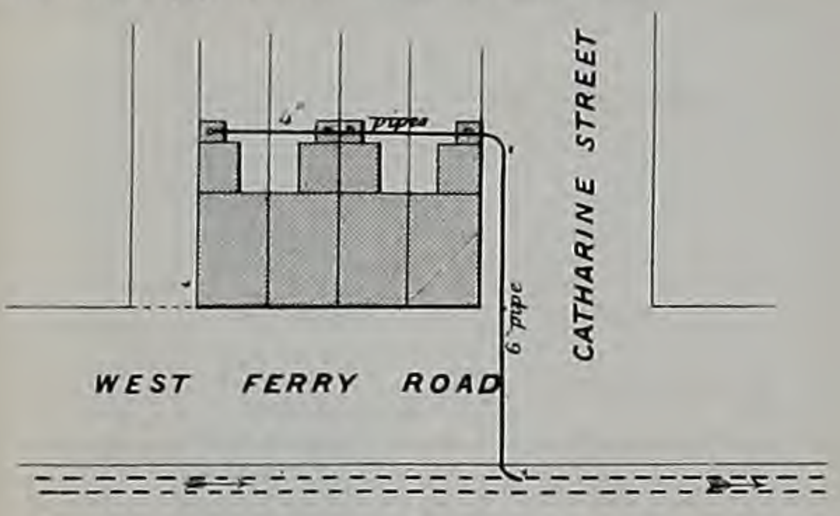
TUBULAR SYSTEM OF DRAINAGE.

POPLAR DISTRICT.

PLANS OF UNITED AND SEPARATE DRAINAGE BY 4 IN & 6 IN GLAZED STONE-WARE PIPES.

Nº 2.

Four Houses in the West Ferry Road Poplar, shewing the System of united back Drainage by 4 inch Glazed Stone-ware pipes, executed in October, 1848.

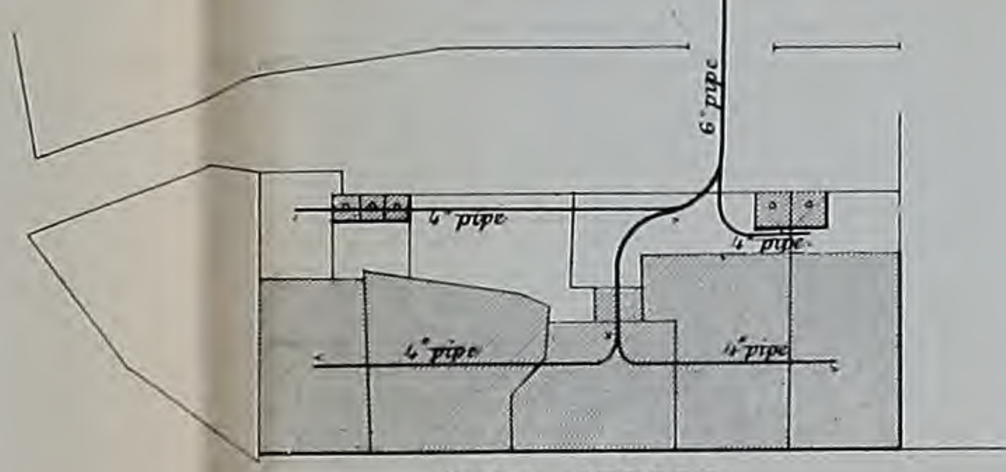


AREA OF PREMISES, 3600 FT

Inclination of outlet main 6 inch Pipe - 1 inch in 10 feet.
D.º of 4 inch Pipes - 1½ Inches in 10 feet.
Average depth of Digging - 5 feet.
There are Pans to the Closets and connections from the Yards & Sinks, The Water is laid on.

Nº 3.

Five Houses in High Street Poplar, shewing the System of united back Drainage by 4 inch Glazed Stone-ware Pipes, executed in September, 1849.

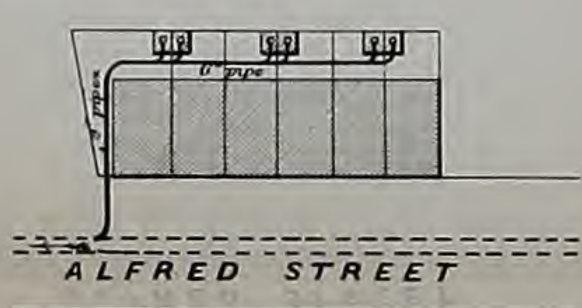


AREA OF PREMISES, 2400 FT

Inclination of 4 inch Drains - 1½ Inches in 10 Feet
There are Pans to the Closets, & connections from the Yards. The Water is laid on.

Nº 4.

Six Houses in Alfred Street, Poplar; shewing the System of united back Drainage by 6 inch Glazed Stone ware pipes, executed in September, 1847.



AREA OF PREMISES 2520 FT

Inclination of 6 inch Pipe - 1 inch in 10 feet
Average depth of digging - 5 feet
This Drainage takes the overflow from the Cesspools to the Privies in the Yards; there are no pans to the Privies. The Water is laid on to the Houses, but not to the Privies.

Nº 5.

Four Houses in Dawson's Alley, Alfred St. Poplar, shewing the System of united back Drainage by 6 inch pipe & 4 inch branch Glazed stone ware pipes: executed in November, 1848

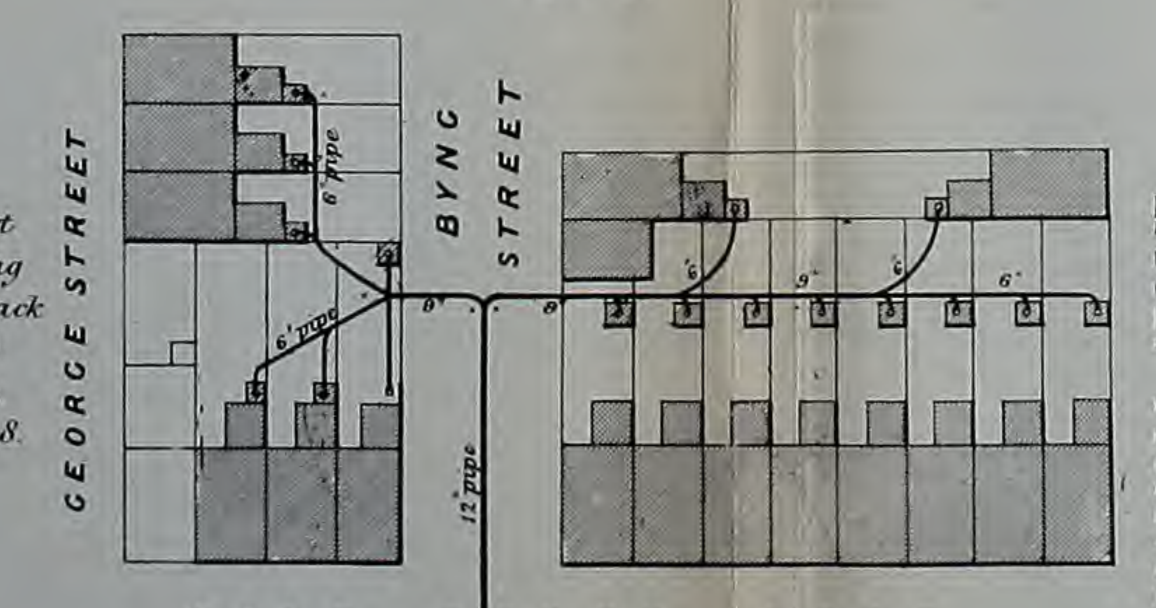
AREA OF PREMISES, 2650 FT

Inclination of 6 inch Main Pipe - 1½ Inches in 10 Feet
Average depth of Digging - 6 feet
There are connections from the Yards and from two Closets; no Pans to the Closets. The Water is laid on to the Houses, but not to the Closets or Privies.

Nº 6.

Nº 6.

Sixteen Houses in the West Ferry Road, Poplar, shewing the System of combined back Drainage by 12, 9, & 6 inch Glazed Stone ware Pipes, executed in September, 1848.



AREA OF PREMISES 22500 FT

Inclination of Drains 1 in. in 10 feet.
Average depth of Digging - 6 ft 6 in.
To 15 Houses there are connections from the Yards & Closets, the Closets have Pans, & the Water is laid on.
To one House, M.º Allen's, the Drains take the overflow from the Cesspools; no Pan to Closet; there is a connection from the Yard. The Water is laid on to the House, but not to the Privy.

Scale.
50 40 30 20 10 0 50 100 150 Feet

200, P.114
Standidge & C.º Litho London.

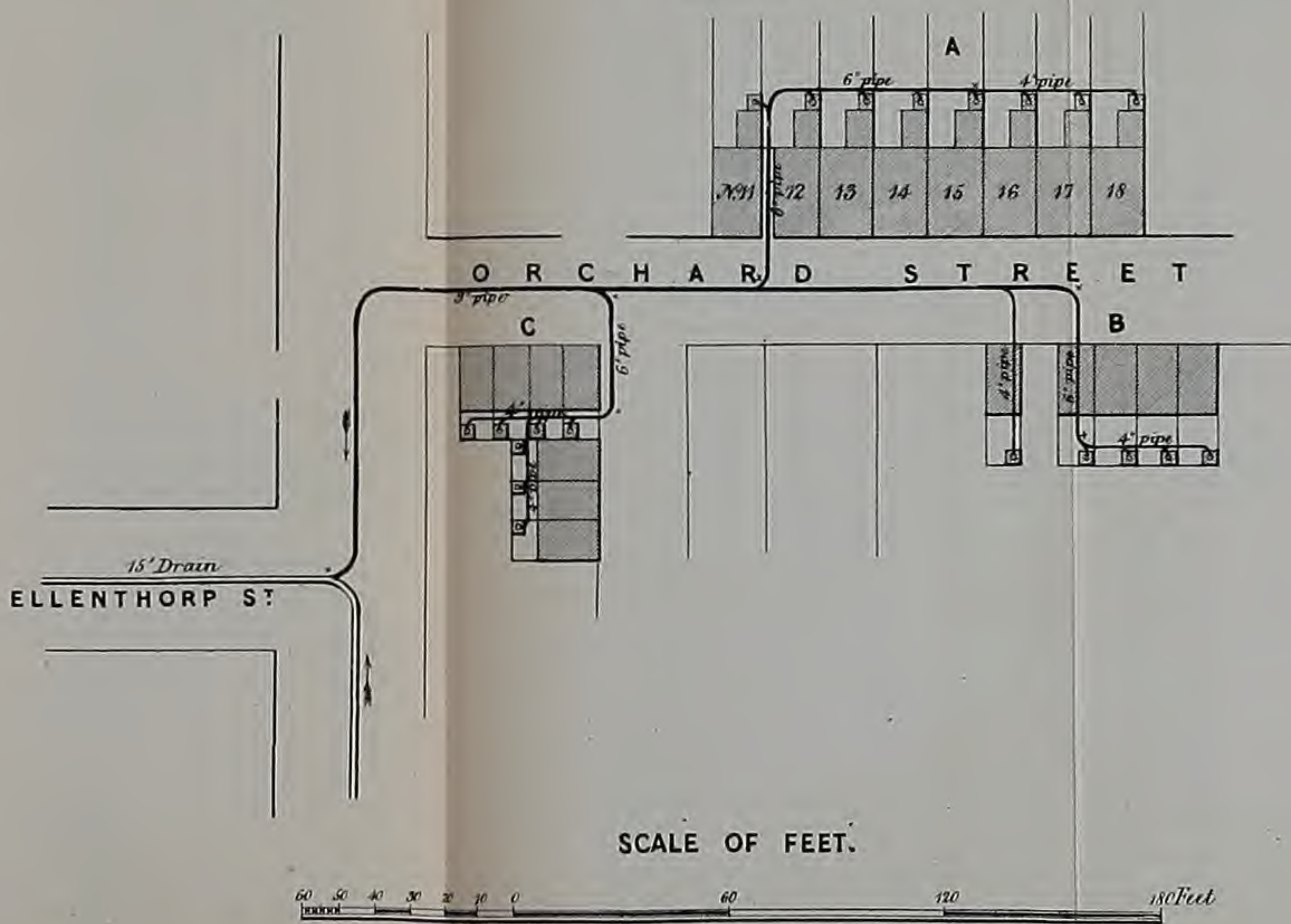
PLAN OF COMBINED BACK DRAINAGE;

ORCHARD STREET, POPLAR.

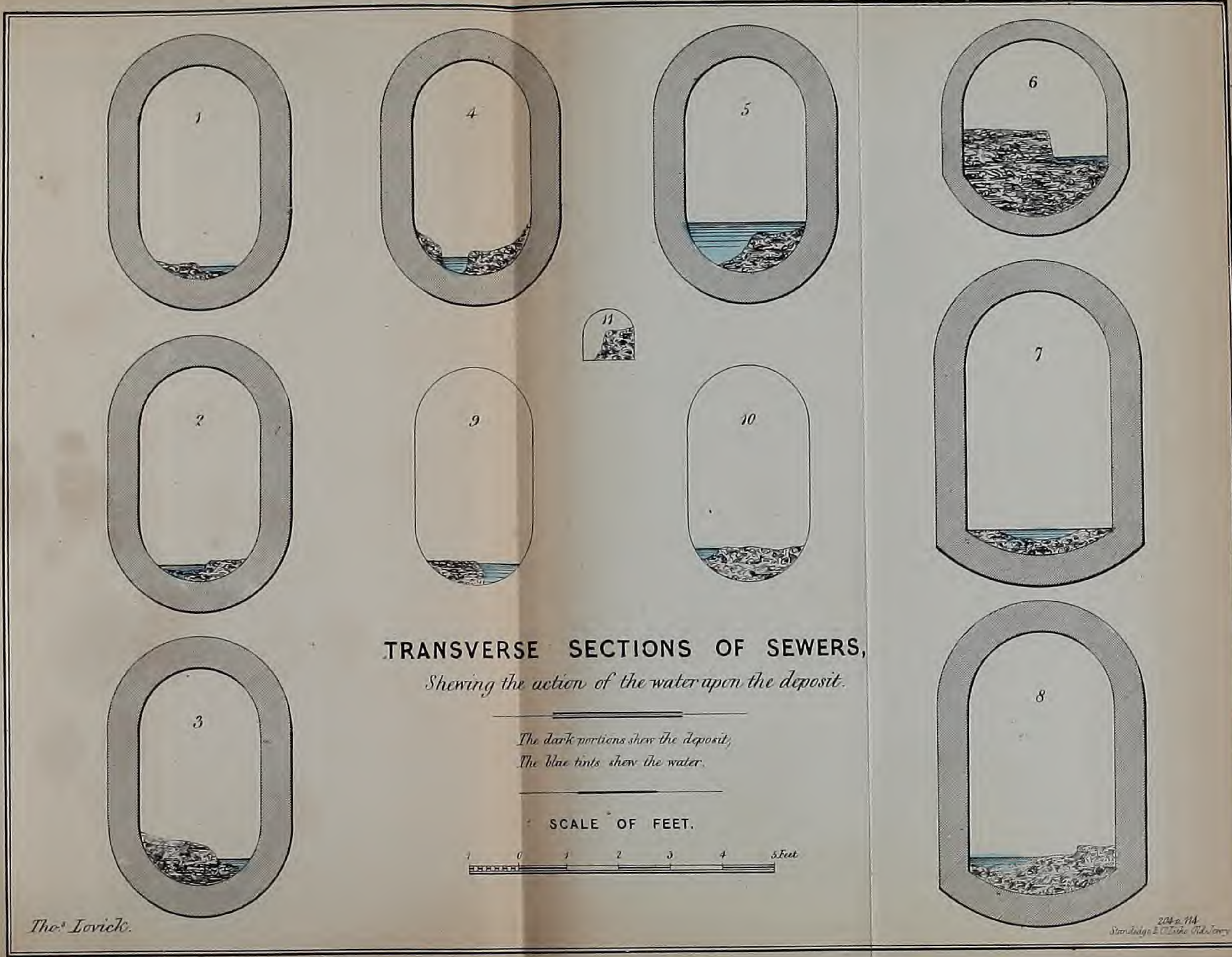
Executed October 1848.

Note,

AREA OF PREMISES 11560 SQUARE FEET,
Depth at Junction 4 feet 6 inches,
Inclination 1½ inches in 10 feet,
There are no Water Closets, – the overflow Water from the Cesspools under the Privies is conveyed away by the Pipes.
Water is laid on to the Houses, but not to the Privies.

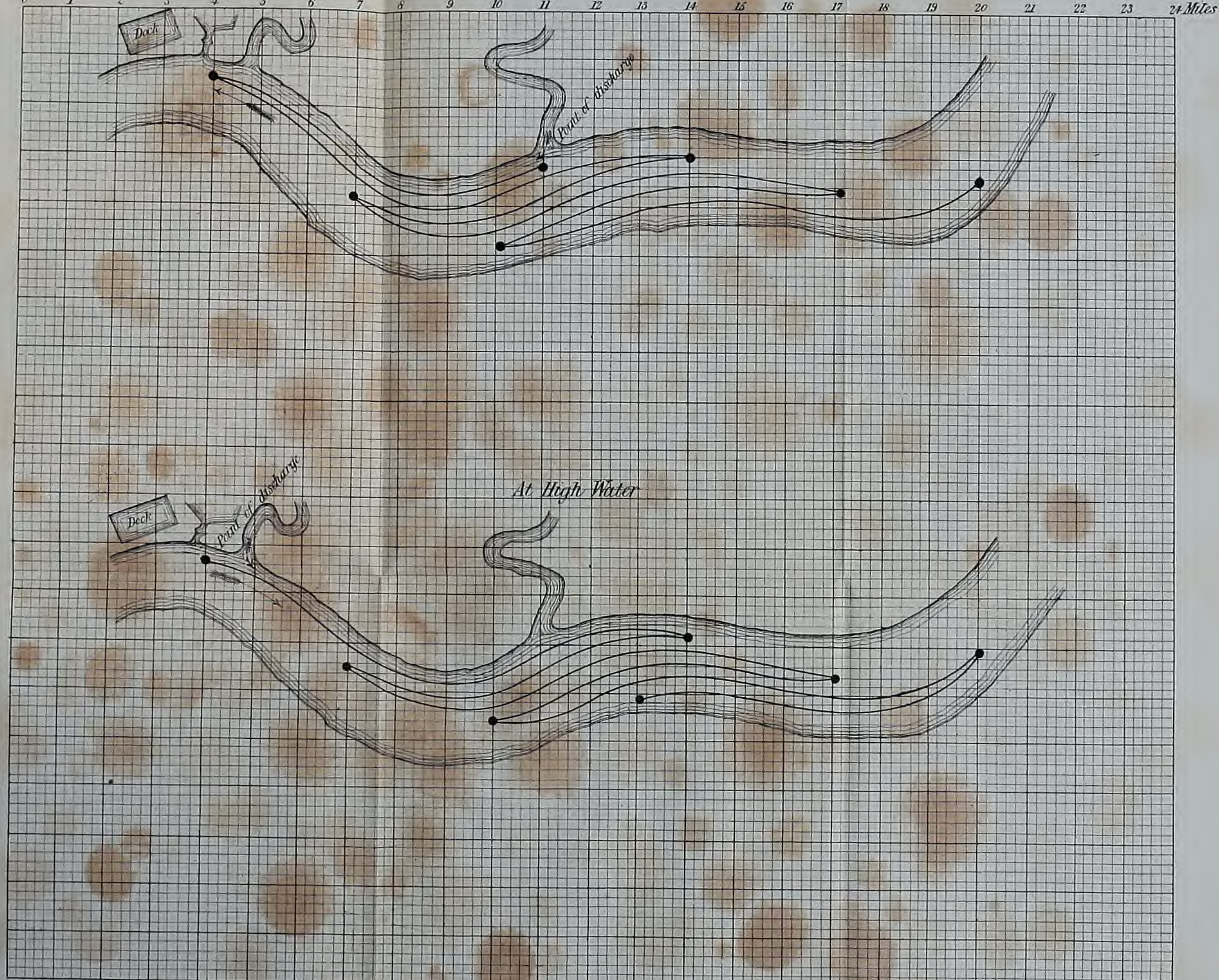


201 p. 114.
Standidge & Cº Litho. Old Jewry.


1
4
5
6
11
7
2
9
10
TRANSVERSE SECTIONS OF SEWERS,
Shewing the action of the water upon the deposit.
3
8
The dark portions shew the deposit;
The blue tints shew the water.
SCALE OF FEET.
1 0 1 2 3 4 5 Feet
Thos. Lovick.
204 a 114

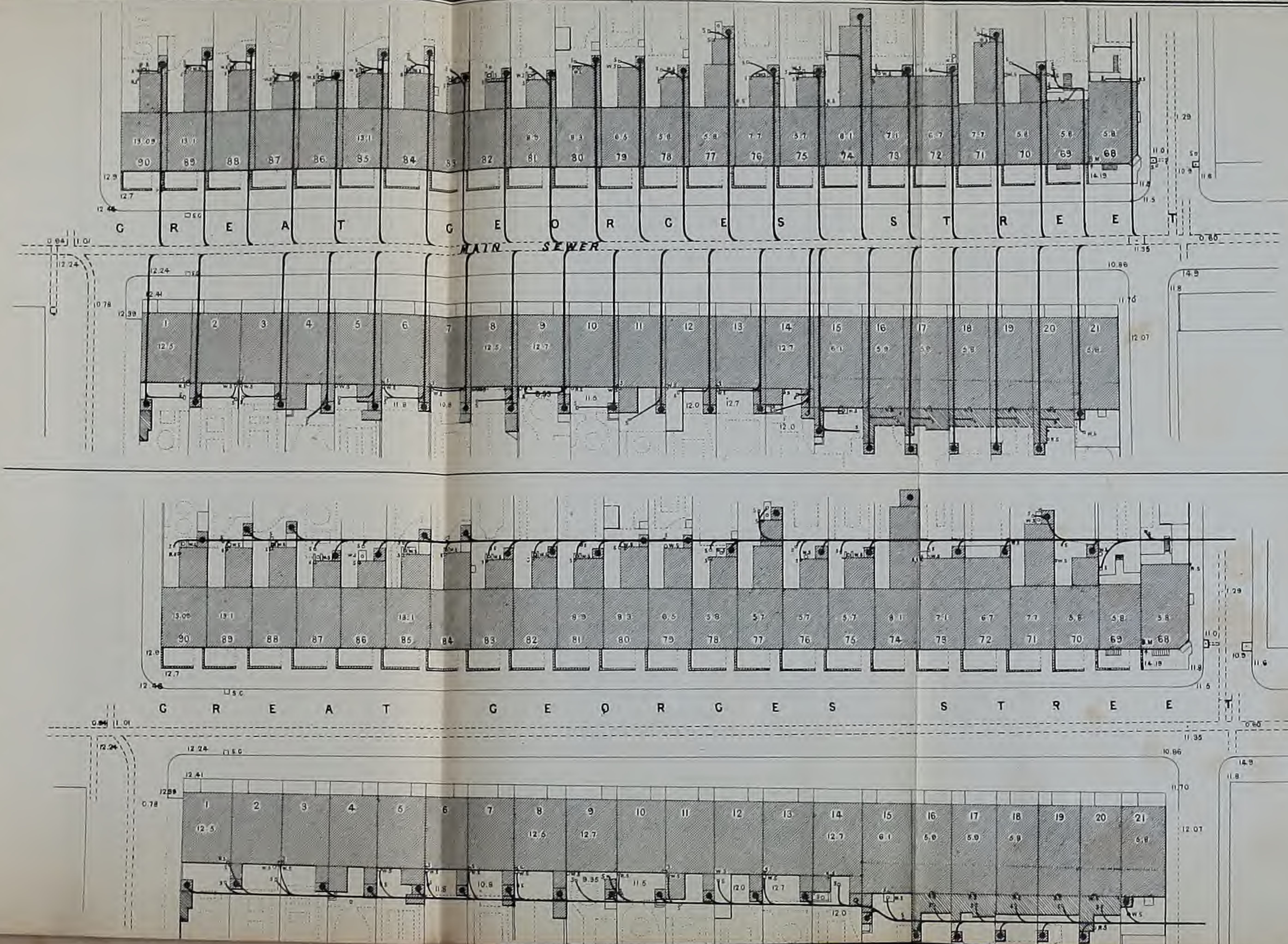
Diagrams illustrative of the flux and reflux of the Tidal Waters in the River Thames, on a float discharged at the periods of High and Low Water.

At Low Water.



Standidge & Co. litho London.
235 p 115.

PART OF SURREY & KENT DISTRICT.



SEPARATE DRAINAGE.

Total length of Drains 3686 Feet.

Estimated Cost with Brick Barrel Branches £ 910.19.0

D° D° 4 in. pipe D° £ 467.9.6

BACK DRAINAGE.

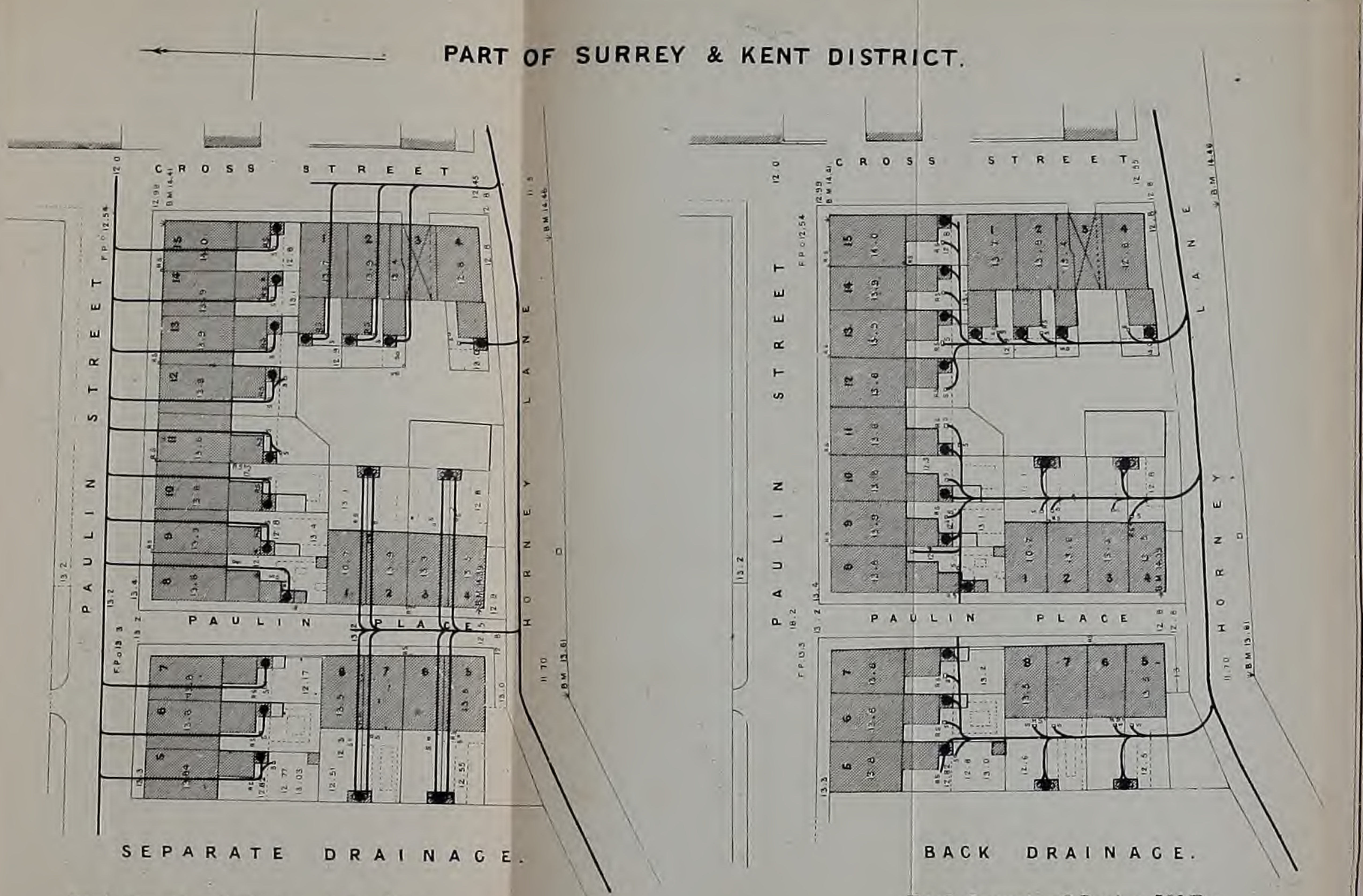
Total length of Drains 1544 Feet.

Estimated Cost £ 83.11.10

Note. The Black Spots indicate existing Cesspools

Standidge & Co. Litho. Old Jewry

PART OF SURREY & KENT DISTRICT.

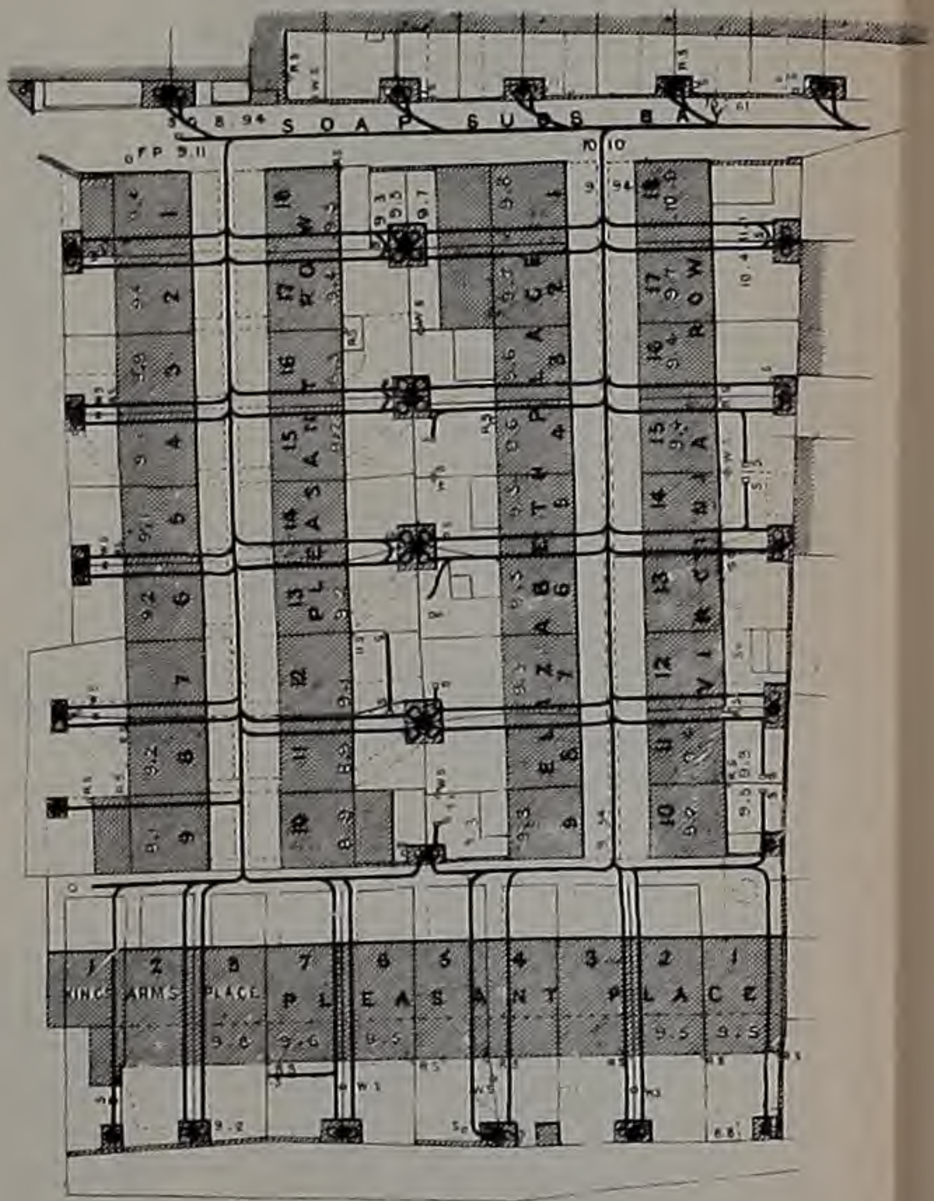


Total Length of Drains 1437 Feet.
Estimated Cost with Brick barrel branches £ 305. 7. 0.
D.o 4 inch pipe D.o £ 131. 13. 6.

Total Length of Drains 785 Feet.
Estimated Cost £ 45. 12. 6.
Note – The Black Spots denote Cesspools.

207.P.114.
Standidge & C.o Litho. Old Jewry

PART OF SURREY & KENT DISTRICT.

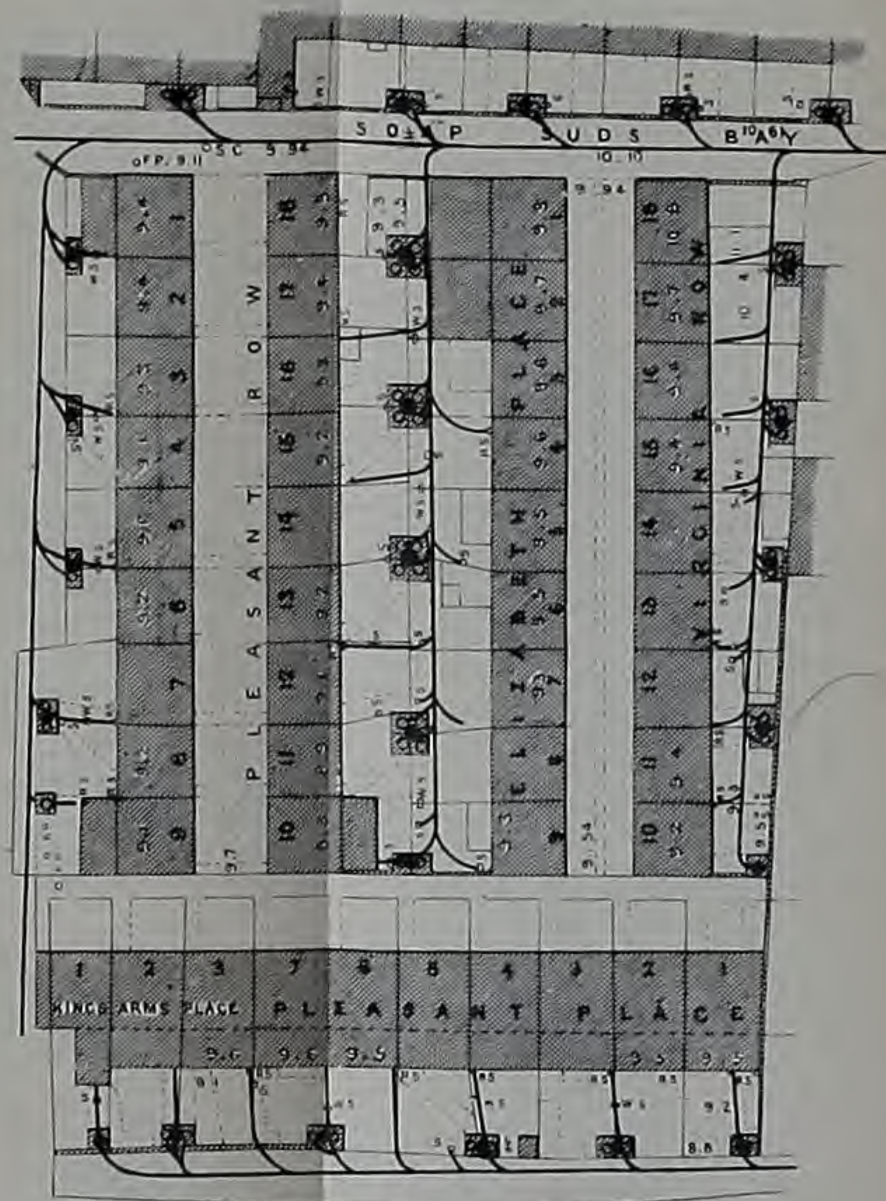


SEPARATE DRAINAGE.

Total Length of Drains 1892 Feet.

Estimated Cost with Brick barrel branches £ 390. 4. 0.

D^o 4 inch pipe D^o £ 178. 19. 8.

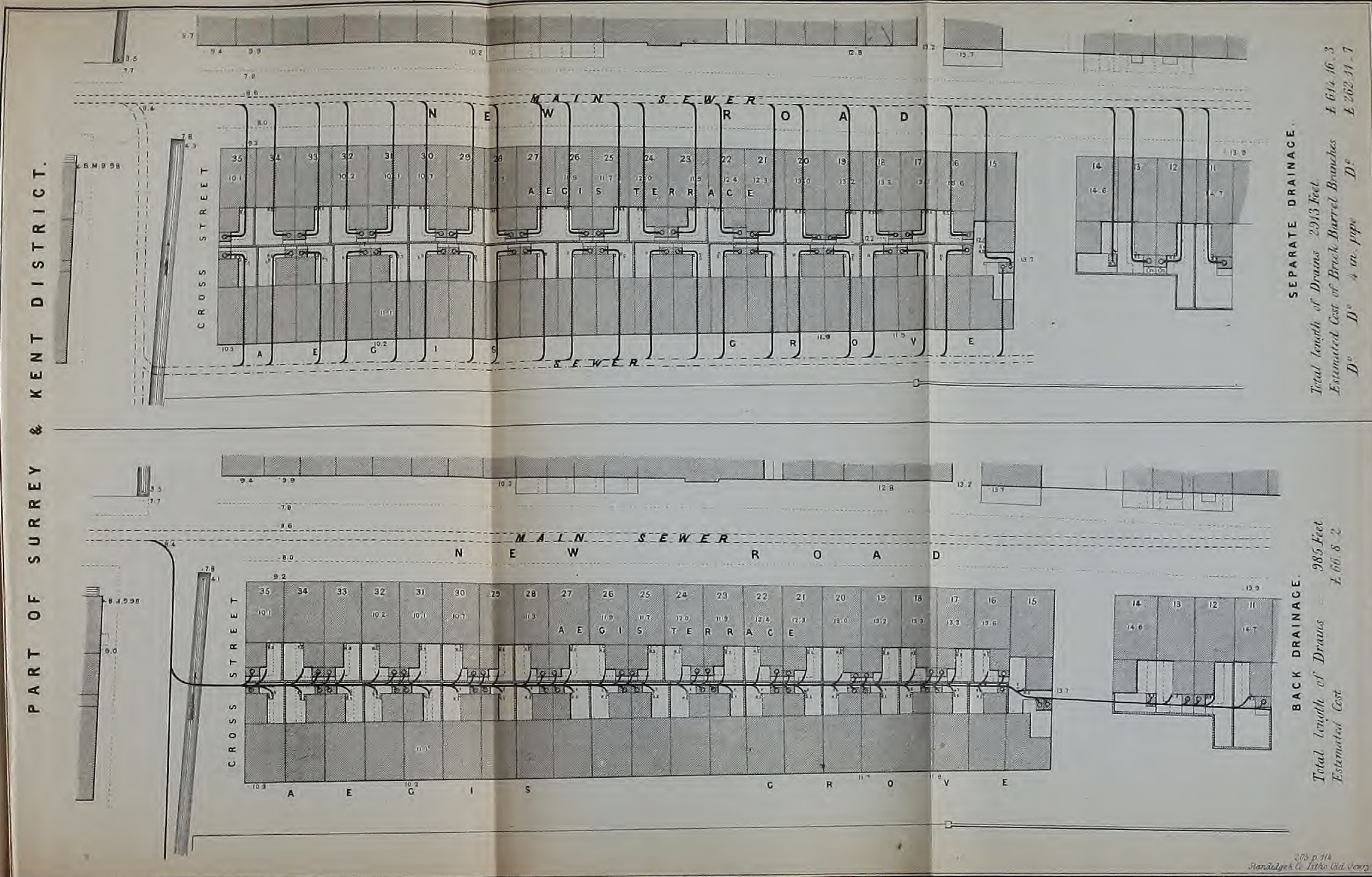


BACK DRAINAGE.

Total Length of Drains, 1143 Feet.

Estimated Cost £ 66 . 6 . 2

Note — The Black Spots denote Cesspools.


PART OF SURREY & KENT DISTRICT.
MAIN SEWER
NEW ROAD
CROSS STREET
AEGIS TERRACE
AEGIS GROVE
SEWER
SEPARATE DRAINAGE.
Total length of Drains 2913 Feet
Estimated Cost of Brick Barrel Branches £ 614. 16. 3
D° D° 4 in. pipe D° £ 262. 11. 7
BACK DRAINAGE.
Total length of Drains 985 Feet.
Estimated Cost £ 66. 8. 2
205 p. 314
Standidge & C. Litho Old Jewry